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Ecology of Suspected Damaging Coyotes and Their Interactions with Domestic Poultry and Livestock

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ECOLOGY OF SUSPECTED DAMAGING COYOTES AND THEIR INTERACTIONS WITH DOMESTIC POULTRY AND LIVESTOCK

by

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INTRODUCTION

An ecological investigation of suspected damaging coyotes was conducted in southeastern Nebraska from May 1975 through August 1976 to fulfill research requirements for an M.S. degree in Wildlife Ecology. Results of this investigation are organized into four sections which have been submitted for publication in scientific journals. Each paper was written according to the style required by the respective journal.

Fifteen coyotes were captured near predation sites with steel traps or snares, 14 were outfitted with radio-transmitters and monitored for periods ranging from 1 to 303 days. The main objective of the study was to document domestic poultry and livestock losses to radio-tagged coyotes. Eight coyotes showed evidence of causing depredations. These data are presented in the first section.

A toe-clipping technique was developed to identify tracks of study coyotes in snow and soft soil, particularly at predation sites. The results of this research are presented in the second section.

The movements of study coyotes were monitored while attempting to document predation. Data on home range, activity, and distance traveled during a 24-hour period were analyzed according to six biological seasons of the coyotes and are presented in the third section.

The last section of the thesis includes data on the proximity of coyotes to den sites and the interactions of a mated pair.

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POULTRY AND LIVESTOCK DEPREDATIONS BY RADIO-TAGGED COYOTES[1]

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Abstract: Fifteen suspected damaging coyotes (Canis latrans) were captured near poultry and livestock loss sites, 14 were outfitted with radio-collars. Eight coyotes showed evidence of causing depredations. A mated pair was suspected of killing 217 turkeys from 4 June to 14 August 1976. During 13 of 14 evenings of radio-tracking, one or both of the mates were located at loss sites; turkey losses were found on the 13 subsequent mornings. Territoriality of the mates may have excluded other coyotes from the loss site.

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Recent concern over predator control in the United States has prompted numerous studies of coyote behavior, ecology, damage assessment, and depredation control. Little factual information is available concerning those coyotes causing damage to domestic poultry and livestock. Percent of coyotes causing damage and frequency of kills by depredating animals is largely speculative. This study was undertaken to provide factual information on poultry and livestock depredations by radio-tagged coyotes during 1975 and 1976.

We thank L. I. Bevans, R. M. Bevans, W. B. Bevans, B. L. Bevans, and E. V. Sheary for the use of their turkey farm as a study site and assisting with the study. Appreciation is extended to W. W. Sahs, W. G. Fulton, D. R. McClure, and the University of Nebraska Field Lab crew, for providing a second study site and assisting with the study. We also thank R. M. Case and H. L. Gunderson for reviewing the manuscript and J. L. Allison for typing the manuscript.

STUDY AREA

The study was conducted on the Bevans turkey farm in northeastern Lancaster County, approximately 8 km ENE of Lincoln, Nebraska and on the University of Nebraska Agricultural Field Lab, in southeastern Saunders County, approximately 33 km NNE of Lincoln (Fig. 1). Topography of the turkey farm is predominantly uplands with low rolling hills. The field lab is a flat upland area with a few gently rolling hills. Both areas were intensively farmed with rowcrops of grain sorghum, corn, and soybeans; small grains of wheat and oats; and forage crops of brome grass, native grass, and alfalfa. Waterways

were generally planted to brome and native grasses. Woody vegetation occurred along creek bottoms and fence rows.

The turkey farm consisted of two range production areas, sites A and B (Fig. 1) located 1.2 km apart. Site A, an "L" shaped 48 ha area, was enclosed by a 2 m tall woven wire fence except for approximately 300 m of deteriorated 1 m tall fencing. Site B (61 ha) was completely enclosed by a 2 m tall woven wire fence. Coyotes entered both sites through holes dug under fences. Turkeys were raised in brooder houses until 7 weeks old. They were then moved to portable range sheds on both sites, or semiconfinement houses on the east side of site A for the final 10 to 12 weeks of growth. Range sheds were portable buildings used for roosts, feed, and water sites. Range sheds were usually placed in groups accomodating 5,000 to 12,000 turkeys. Two semiconfinement houses built prior to 1975 were each surrounded by a 1 m fence and two semiconfinement houses built in 1976 were surrounded by 2 m fences. The fences around the new semiconfinement houses were essentially coyote proof, but coyotes and turkeys could move through the fences surrounding the older houses. Each semiconfinement house contained approximately 6,000 turkeys. Approximately 130,000 turkeys were produced on the turkey farm each year.

In addition to turkeys, approximately 400 sheep (200 ewes and 200 lambs) grazed on sites A and B during the study. Most lambs were born in late April and early May. A few sheep also grazed in neighboring pastures.

Approximately 400 ewes and 20 rams grazed in sections of a 65 ha pasture on the university field lab during spring, summer, and

fall, 1975 and 1976. The pasture was enclosed and cross fenced with a 1 m high woven wire fence with barbed wire above. An estimated 600 cows and 500 calves also grazed in various pastures on the field lab. Pigs numbering 1,000 to 1,500 were raised on the area during 1975; about 75 percent of these were reported located in fenced pens accessible to coyotes. During 1976, approximately 90 pigs were accessible to coyotes. Pigs were not placed in areas accessible to depredations until they weighed over approximately 23 kg.

MATERIALS AND METHODS

Snares and number 3 steel traps were set intermittently near predation sites on the field lab during May, June, August, September, and December 1975 and on the turkey farm from mid-May 1975 through mid-April 1976 except for October and February. Captured coyotes were outfitted with 151 MHz radio-telemetry collars. Coyotes were toe-clipped (Andelt and Gipson 1977) to permit track identification at predation sites. Signals were received on a portable receiver (Model La-12, AVM Instrument Company, Champaign, Ill.) using a car-top mounted null-peak antenna system or a portable four element yagi antenna. Locations of study coyotes were determined by radio-telemetry, sightings, and toe-clipped tracks in soft soil and snow.

Turkeys killed by coyotes were usually bitten on the head, neck, or back. Losses were determined by the senior author and from owner loss records. Locations of study coyotes were plotted on cover maps along with locations of dead turkeys. The distance between the coyote and the nearest dead turkey was calculated. Dead turkeys

were usually gathered each day by the producer and placed in an open dump on the south edge of site A.

Coyotes were usually located each week, but when traps were set, most coyotes were located daily. The movements of study coyotes were monitored at 1 hour intervals throughout a 24-hour period each month from May 1975 to July 1976. Two coyotes that consistently killed turkeys were intensively monitored during evening hours from late June to mid-August 1976.

RESULTS

Fifteen suspected damaging coyotes were captured near predation sites; 14 were outfitted with radio-collars. The remaining coyote was found dead in a snare. Eight of the 15 coyotes showed either direct (domestic prey in stomach or scat) or indirect (coyote located near loss sites) evidence of causing damage (Table 1).

Turkey Farm 1975

Seven coyotes (3,4,5,6,7,8,10) were captured at the Bevans turkey farm during late spring and summer 1975. Turkeys were accessible to coyotes while on range from 16 April to 22 November 1975. The first turkey losses were reported on 10 May; coyotes were captured near loss sites from late May through September (Table 1). Three of the captured coyotes (3,6,7) were apparently causing damage. Male 3 was found dead near site B five days after being outfitted with a radio-collar. His stomach contained turkey feathers. Female 6 was killed in a snare on 23 June while moving through a hole under the fence surrounding site B. Two toes were missing from her fore-leg,

she apparently escaped from a trap set at a hole under the fence surrounding site A where two toes were found on 30 May. Turkey remains were found in her stomach. Female 7 was snared around the chest while entering site B. She was found dead the next day and the stomach contained turkey remains.

Coyotes 4,5,8, and 10 did not show evidence of killing turkeys during the period they were monitored. Male 4 was located during daylight on 8 of 9 days following capture (11-19 June) and was found within 1 km of turkey pens, yet no losses were reported. Female 5 ranged through the area immediately east of site B for approximately 3 months after capture. Her range included sites A and B during the next 1.5 months before shifting to an area several km to the north. No turkey losses were attributed to this coyote. Females 8 and 10 were found dead 1 and 10 days, respectively, after capture; no depredations by these coyotes were noted.

The turkey producers reported losing 115 turkeys to predators during the 1975 season. Most of these losses were attributed to coyotes, although some losses were due to great horned owls (Bubo virginianus). Ewes and lambs were present on both sites, but no losses were reported.

Turkey Farm 1976

Coyotes 11,12,13,14 and 16 were outfitted with radio-collars before turkeys were placed on range during the 1976 season. Traps were removed prior to the introduction of turkeys to avoid frightening coyotes away from turkey pens. Turkeys were placed in semiconfinement and range sheds at site A on 3 and 19 May, respectively. Coyote 12

was monitored for almost 7 months. Her range included both sites, but no losses could be attributed to her during the period monitored. However, she was recaptured while entering site B on 29 September 1976 as part of a continuing investigation by another researcher; scats left at the trap site contained turkey feathers. Female 13 and male 16 ranged through an area east of the turkey farm for almost 7 and 4 months, respectively, but were not located within the pens.

Male 11 was captured on 3 December 1975 and female 14 was captured on 4 April 1976. The two coyotes were first located together on 7 April. Numerous subsequent locations of the coyotes together suggest they were mates. The home ranges of coyotes 11 and 14 (Fig. 1) as determined by more than 8 and 4 months of radio-tracking, respectively, included site A. Ranges of the two coyotes were nearly identical. Frequent movements around site A by these coyotes and the absence of sign of other coyotes in the area suggest territorial behavior.

On 12 January 1976, male 11 was located near an open dump containing turkey and ewe carcasses on site A. On 31 January, coyote 11 in company of another coyote, possibly female 14, was snow-tracked on site A. Both coyotes converged upon the dump and apparently consumed carrion. The carcasses probably served as an important winter food source.

We were notified on 27 June that turkeys were being lost, possibly to coyotes on site A. Eighty-nine losses were recorded by the turkey producer at range sheds located on the southern end of the area from 4 to 27 June. Depredations apparently began 16 days

after turkeys were moved to the range on 19 May. Male 11 was located near the loss site at 0140 on 9 June (Table 2). On 11 June, we investigated an area 2.4 km west of site A which was frequently used by coyotes 11 and 14; two turkey feathers were located near a den complex. Toe-clipped tracks of coyotes 11 and 14 were located on site A on 27 June following 1 to 2 cm of rain during the night of 23-24 June. The tracks, made in wet soil, indicated the coyotes were inside the enclosure shortly after the rain. The producer found 11 dead turkeys on 24 June.

Coyotes 11 and 14 were located at one-hour intervals during 14 evenings and early mornings from 27 June to 14 August (Table 2). Other study coyotes were periodically located. The senior author found turkey losses at the range or semiconfinement houses on 13 mornings after locating one or both of the coyotes on site A the preceeding evening. No losses were found one morning following a night when neither coyote was located within the enclosure. Male 11 was located on site A on 11 of these nights and adjacent to it on the other three. Female 14 was located on site A on 10 nights and adjacent to it on three others. Male 11 entered the site twice on three different nights; female 14 entered the site twice during one night.

Fourteen locations of male 11 were on site A, 13 were in the immediate vicinity of losses. The remaining location, was made when the coyote was leaving the site. Eleven locations of female 14 were on site A and all were near losses. Coyotes 11 and 14 were located an average of 42 and 38 m, respectively, from the nearest killed

turkey found the following morning.

Male 11 was most frequently located on site A at 2400; time of locations ranged from 2200 to 0500. Female 14 was located on the site most frequently at 0100; locations ranged from 2200-0400.

Hourly radio-tracking data indicated coyotes 11 and 14 spent a maximum of two hours on site A per foray. During the night of 8-9 July, coyotes 11 and 14 were monitored at 15-minute intervals when they were near the site of losses. At 0030, the coyotes were located together adjacent to site A. At 0045 and 0100, both coyotes were at the loss site. At 0115, male 11 was still at the loss site, but 14 was moving away. Both coyotes were outside the enclosure at 0130. These data indicate a maximum time of 45 and 60 minutes and a minimum time of 15 and 30 minutes for 14 and 11, respectively, to have been at the loss site.

Female 14 was first located at the semiconfinement houses on 27 June (Fig. 1). During nine subsequent tracking shifts, neither coyote 11 nor 14 was located there. The first losses at the semiconfinement houses were found on 17 July. During the night of 19-20 July, female 14 was again located at the semiconfinement houses. The turkey producer reported seven losses the following morning. The location of these losses was approximately 39 m from the radio-location of 14.

The senior author found 38 dead turkeys compared to 37 reported by the turkey producer after 14 nights of radio-tracking and one morning of locating toe-clipped tracks near dead turkeys. Some daily variation existed between the producer's and senior author's loss

estimates. This variation could be due to the producer not checking for losses each day and recording losses for two nights as one. Eighty-nine turkeys were reported lost from 3 to 27 June, and 128 losses were reported from 28 June to 14 August. The total loss estimate on site A was 217 turkeys in 72 days. This represents an average loss of 3 turkeys per day or approximately $11.12 per day. The average weight of turkeys when killed was estimated according to their age from Jensen (1976) and multiplied by an estimated production cost at market time of $0.926 per kg.

Coyotes ate a portion of one to three turkeys during each of eight nights from 5 July to 14 August on site A. Some turkeys were bitten on the head or neck but not consumed. The greatest amount of turkey flesh consumed was estimated at 5 kg.

Twenty-nine turkey losses were reported by the producer on site B (Fig. 1) from 22 July to 13 August, almost 2 months after turkeys were placed on the range. A tracking shift was conducted during the evening of 13-14 August. No study coyotes were located on site B, but 21 losses were found the following morning. Numerous coyote tracks were observed in wet soil at the loss site and none showed evidence of toe-clipping. These losses in addition to the 217 losses on site A amounted to approximately 267 total losses to coyotes from 4 June to 14 August.

Sheep were grazed on both sites during 1976, but no losses were reported.

Field Lab 1975, 1976

Three coyotes (1,2,9) were captured on the field lab during

spring and summer, 1975 (Table 1); two showed evidence of causing depredations. Two ewes and one holstein calf (approximately 50 to 60 kg) were apparently killed by coyotes during 1975, as evidenced by neck wounds similar to those reported by Wade (1973), Connolly et al. (1976), and others. The area herdsman reported additional losses of two ewes. The first suspected coyote-killed ewe was found on 2 May; coyotes 1 and 2 were captured shortly after this loss. Coyote 9 was captured near the dead calf on 8 September.

Coyotes 1 and 9 were radio-tracked for 24 hours beginning at 0845 on 21 September. They were located adjacent to the sheep pen at 0200 on 22 September. At 0245 and 0300, coyotes 1 and 9, respectively, were located within the sheep pen. Both coyotes were located outside the pen 1 hour later. A dead ewe with neck wounds and partially consumed hind quarters was found in the pen at the approximate location of the coyotes. Coyote 1 and/or 9 may have killed the ewe. The home ranges of those coyotes included the sheep pen, yet there were no other known depredations. Coyote 1 was shot by a hunter during fall 1975; its stomach contained 319 ml of fresh hereford calf meat and hair. The source of the calf tissue was not known.

Coyote 2, captured within the sheep pen on the field lab, was not located near the pen during the subsequent eight months of radio-tracking. Depredations by this coyote were not detected.

No depredations were reported on the field lab during the study in 1976.

DISCUSSION

The high correlation of coyotes 11 and 14 near turkey losses on site A suggest the two coyotes were responsible for most, if not all, losses during radio-tracking shifts from 27 June to 14 August. No other coyotes were known to be on site A. The radio location of male 11 and toe-clipped tracks of coyotes 11 and 14 near the site of losses, and turkey feathers at their den suggest they may also have been responsible for the losses sustained between 4 and 27 June. These combined losses totaled 217 turkeys or an approximate production value of $801. If these two coyotes were responsible for 217 losses, an average loss per coyote during the 72 days was $400.50.

Data from mates 11 and 14 indicated they spent 30 to 60 minutes and 15 to 45 minutes, respectively, at turkey kills during the evening of 9-10 July 1976. All other forays into turkey pens when kills occurred lasted less than 2 hours. Food deprived coyotes studied by Connolly et al. (1976) fed on a sheep carcass an average of 25 minutes. They also found food deprived coyotes ate an average of 2 kg of sheep flesh per meal. The maximum amount of turkey flesh consumed where our mated pair was damaging was approximately 5 kg. It is reasonable to assume that the two coyotes could have consumed this amount, especially if some of the turkey flesh was later regurgitated for their pups.

The producer reported 37 turkeys lost to coyotes compared to 38 found by the senior author after 15 different tracking shifts and observations of toe-clipped tracks near losses. These data

indicate the turkey producer was making conservative estimates of coyote losses which is contrary to the belief that verified losses are usually lower than those claimed by stockmen (Wagner 1972, McCabe and Kozicky 1972).

The presence of traps and snares at predation sites appeared to significantly reduce turkey losses during 1975. The death of three coyotes with turkey in their stomachs along with the possible frightening affect of being caught, seeing, or hearing coyotes captured possibly reduced losses to 115. The turkey producer reported losing approximately 275 turkeys per year to predatory animals prior to our study. Most of these losses were attributed to coyotes. Control attempts by the producer before our study included setting a few traps, blocking holes dug under the enclosures, placing clothing worn by humans near turkey pens, and sleeping near the turkeys. Loss of 267 turkeys in 1976 did not include losses sustained after 14 August.

Although the majority of study coyotes apparently caused damage, the data support the belief of several workers that most coyotes do not kill sheep (Gier 1968:108, Henderson 1972). Sheep were grazed on both turkey farms and near the farms during 1975 and 1976, yet no sheep losses were reported. Turkeys appeared to be preferred over sheep as a food source on the turkey farms. Possibly, sheep would have been killed if turkeys had not been present. Connolly et al. (1976) found some coyotes were more likely to kill sheep than others, but most of the coyotes they studied killed sheep even though they did not have previous predatory experience. Gipson (1975) reported

that 33 percent of the coyotes caught in response to damage complaints had the food item reported damaged in their stomach.

Management Implications

Coyotes apparently learn to kill and eat certain prey items. Lehners (1976) indicated naive, food-deprived coyotes appear to kill rats while "playing" with them and eat them only if their skin is torn and flesh is exposed. The open dump containing turkey and sheep carcasses on site A appeared to serve as an important food source for coyotes 11 and 14 during winter. The coyotes may have learned to identify live turkeys as prey items by consuming turkey carrion. The carrion may have served to keep these coyotes near the farm and thereby increased their probability of preying on turkeys during summer.

Territoriality may be a limiting factor for the number of coyotes causing depredations. The data collected on coyotes 11 and 14 suggest they were territorial and possibly excluded other coyotes from site A. Chesness and Bremicker (1974) monitored the movements of coyotes in Minnesota and concluded that adult females were apparently highly territorial with little overlap in their home ranges, but adult males tended to be more mobile and had more overlapping ranges. Lehner (1976:122) stated "territorial behavior is advantageous for the wildlife manager who can inhibit predation of the local coyotes on livestock." Aversive conditioning with lithium chloride (Gustavson et al. 1974, Garcia 1975) or other agents might condition coyotes holding a territory around loss sites to stop damaging and yet exclude

other coyotes. Possibly, coyotes would cease to defend an area after the domestic prey was found unpalatable. More research is needed in this area.

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Fig. 1. The Bevans turkey farm, including: HR, home range boundary of coyotes 11 and 14 around site A; RS, range sheds, and SCH, semiconfinement houses, where depredations by radio-tagged coyotes occurred; and OD, open dump, containing turkey and sheep carcasses utilized by coyotes during winter.

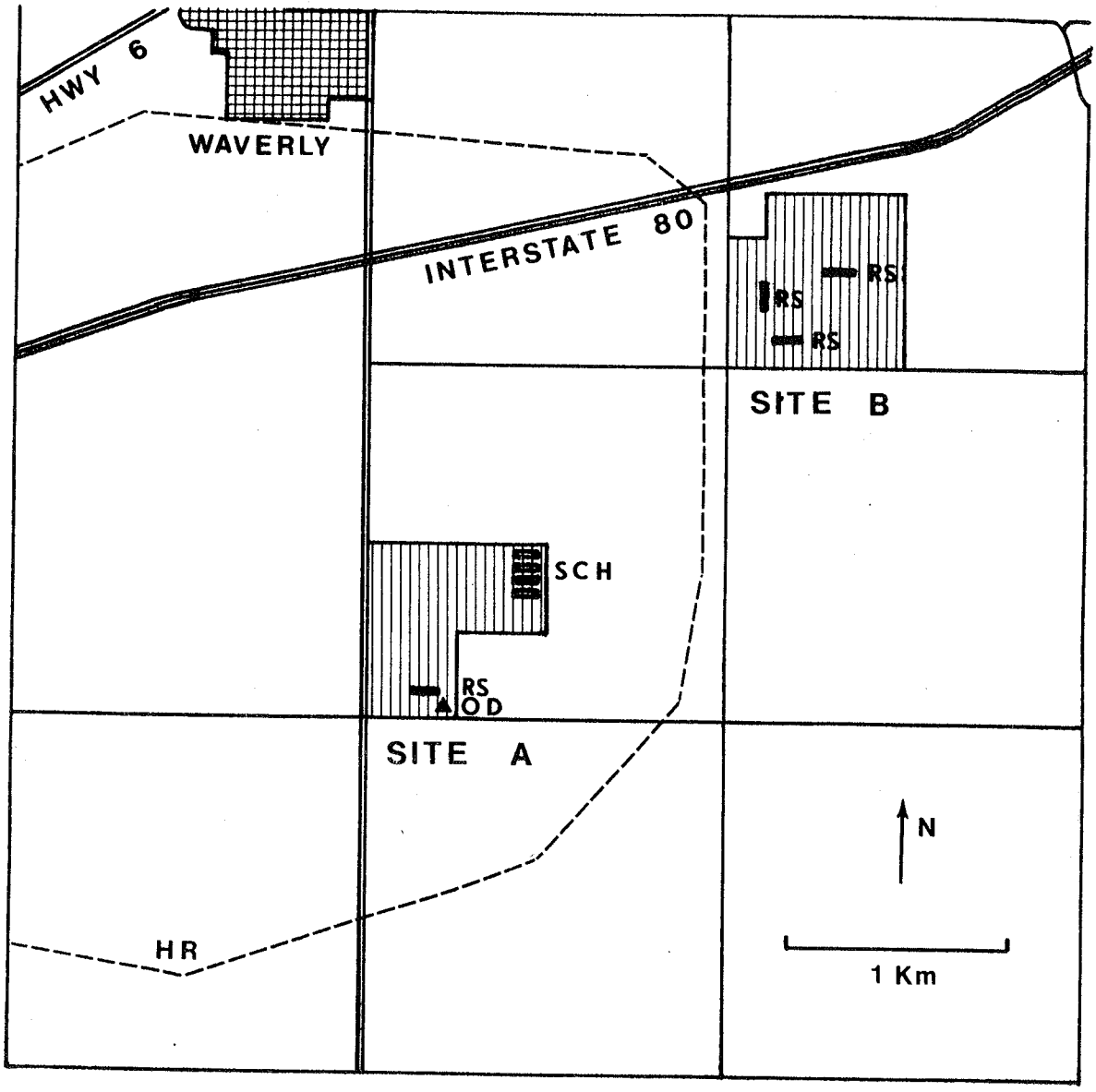
HWY 6
WAVERLY
INTERSTATE 80
RS
RS
RS
SITE B
SCH
RS
OD
SITE A
N
HR
1 Km

Table 1. Background information and evidence of depredations by radio-tagged coyotes.

Coyote	Sex	Capture Site	Date Captured	Date Last Located	Final Status	Evidence of Depredations
1	M	Near dead ewe[a] at field lab	11 May 75	30 Nov 75	Shot by hunter	Located with No. 9 at loss site; calf in stomach
2	M	In sheep pen at field lab	27 May 75	1 Feb 76	Shot by hunter	None
3	M	Under turkey enclosure fence	30 May 75	4 Jun 75	Dead, cause unknown	Turkey in stomach
4	M	Within 10 m of turkey enclosure	10 Jun 75	9 Jul 75	Loss of radio contact	None
5	F	Under turkey enclosure fence	12 Jun 75	20 Mar 76	Transmitter failure	None
6	F	Under turkey enclosure fence	23 Jun 75	23 Jun 75	Dead in snare	Turkey in stomach
7	F	Under turkey enclosure fence	23 Jun 75	24 Jun 75	Dead, snare injury	Turkey in stomach
8	F	Within 10 m of turkey enclosure	25 Jul 75	26 Jul 75	Dead, possibly heat exposure	None
9	F	Near dead calf[a] at field lab	12 Sep 75	10 Jul 76	Alive, transmitting	Located with No. 1 at loss site
10	F	Within 10 m of turkey enclosure	25 Sep 75	5 Oct 75	Dead, possibly leg infection	None
11	M	Between sites A and B	3 Dec 75	14 Aug 76	Alive, transmitting	Consistently located near turkey kills

12[b]	F	Within 100 m of turkey enclosure	20 Jan 76	14 Aug 76	Alive, transmitting	Turkey in scat on 29 Sep 76
13	F	Under turkey enclosure fence	23 Jan 76	14 Aug 76	Alive, transmitting	None
14	F	Under turkey enclosure fence	4 Apr 76	14 Aug 76	Alive, transmitting	Consistently located near turkey kills
16	M	2.2 km ESE of site B	18 Apr 76	10 Jul 76	Loss of radio contact	None

[a]suspected coyote-kill
[b]yearling coyote, others were adults

Table 2. Summary of recorded turkey losses and presence of coyotes 11 and 14 at loss sites on site A.

Date	Losses Andelt	Losses Bevans	Number Partially Consumed	Male 11 Time in Pen	Male 11 Distance From Nearest Kill (m)	Male 11 Time Near Pen	Female 14 Time in Pen	Female 14 Distance From Nearest Kill (m)	Female 14 Time Near Pen
8-9 Jun	--[a]	0[a]		0140					
24 Jun	--[a]	11[a]		----[b]			----[b]		
27-28 Jun	2	1	Unknown	2400 0300	Unknown Unknown		2200	Unknown	
28-29 Jun	2	2	Unknown	2400	17		2300	27	0100-0200
29-30 Jun	0	0	Unknown			2400-0100			
30 Jun - 1 Jul	2	0	Unknown	0230 0300	68 34		2200 0100	26 94	
1-2 Jul	1	0	Unknown	2400	410[c]				2300-2400
4-5 Jul	3	0	2	2400	27		0100	18	
5-6 Jul	1	4	1	2400	73				2300-2400
6-7 Jul	2	8	2			2400-0100	2400	31	
9-10 Jul	2	0	2	0045 0100 0115	9 32 48		0045 0100 0115	10 16 --[c]	
15-16 Jul	3	3	3			2300-2400	2300	9	

19-20 Jul	11[d]	10	Unknown	0200	4		0300	39	2400-0100 0100-0200
23 Jul	4	7	2	----[b]	Unknown	---------[b]			
28-29 Jul	9	9	3	2200	Unknown	0200-0300 0400-0500			0200-0300 0300-0330
11-12 Aug	2	0	Unknown	2200 0300	46 32		0400	80	
13-14 Aug	1	0	1	2200 0500	31 122		0200	63	
TOTAL	45	44			$\bar{X}$ = 42 ± 31.4 SD			$\bar{X}$ = 38 ± 28.9 SD	

[a]Data excluded from totals because researchers were not aware of losses.
[b]Presence of coyote determined by toe-clipped tracks.
[c]Not used in average distance calculation, the coyote was moving away from the loss site.
[d]Seven of these turkeys were reported to the senior author from a site he did not visit.

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TOE-CLIPPING COYOTES FOR TRACK IDENTIFICATION

Toe-clipping has been widely used to mark mammals for identifying individuals or their tracks in studies of activity, home range, homing, and populations. Toe-clipping deermice (Peromyscus leucopus) (Savidge 1973), meadow voles (Microtus pennsylvanicus) (Blair 1940), striped ground squirrels (Spermophilus tridecemlineatus) (Evans 1951), and opossums (Didelphis marsupialis) (Sanderson 1961) provided identification of individuals when recaptured. Tracks of toe-clipped house mice (Mus musculus) (Justice 1961), varying hares (Lepus americanus) (Dell 1957), and raccoons (Procyon lotor) (Stuewer 1943) were used to determine locations of specific animals.

Tracks of canids with abnormal feet have provided location information, but the feet of these canids were not deliberately altered. Tracks of Three Toes of the Apishapa, a legendary wolf (Canis lupus) described by Young (1970), could be identified by a three-toed footmark. Ozoga and Harger (1966) obtained information on the home ranges of two coyotes (C. latrans) by observing tracks with missing toes. Scott and Klimstra (1955) obtained movement information on a fox (Vulpes vulpes) whose track could be identified by a slight deformity of the left front foot.

This paper describes a toe-removal technique for marking coyotes. Tracks with missing toes were used to verify the presence of suspected damaging coyotes at predation sites and for following their trails in snow.

Coyotes were captured near predation sites with snares or number 3 steel traps with offset jaws. One toe was removed from the front foot of 11 coyotes in a systematic order and a toe was missing from the right hind foot of another study coyote. When coyotes were captured in traps, a toe was removed from the foot restrained by the trap so only one foot would be impaired. Each coyote was outfitted with a 151 MH_Z radio telemetry collar.

One coyote was anesthetized with 24.8 mg/kg of sodium pentobarbital (Anesthesal, 64 mg/ml, Norden Laboratories, Lincoln, Ne.), 6 were given 1 cc of a local anesthetic, lidocaine (Lidocaine HCL, 20 mg/ml, Interstate Drug Exchange, Plainview L.I., N.Y.) as described by Rice and Kangstrom (1965), and 4 were not anesthetized prior to toe removal. Those coyotes not anesthetized had suffered moderate foot damage in the trap. Lidocaine or no anesthetic was preferred over sodium pentobarbital because coyotes could be released immediately after toe amputation.

The surgical procedure approximated the technique described by Lumb (1965) for amputating toes of dogs. Loose skin was pulled toward the foot prior to making an incision. Joints were disarticulated between the first and second or second and third phalanges. The digital pad was removed with the phlanx(es). Incisions were closed with sutures on 6 of the 11 coyotes. Observations of recaptured

coyotes and tracks indicated both sutured and unsutured toes healed.

Toe removal did not appear to affect study coyotes adversely, with the possible exceptions noted below. Tracks with missing toes were comparable to adjacent tracks in spacing and depth, indicating coyotes did not favor altered feet. Coyotes with missing toes were observed running on 18 occasions and no lameness was noted. The feet of 2 captured coyotes were examined; both had healed and were being used.

Two toe-clipped coyotes were found dead 11 and 13 days after release. Cause of death was not determined although the leg of one coyote was inflamed. These deaths may have been caused by infection resulting from the trap wound or toe removal. Tracks and sightings of another coyote indicated it favored the altered foot. That coyote's leg was probably frostbitten in the trap. Mech et al. (1971) described a female wolf whose foot was frozen in a trap before she was fitted with a radio collar. She was often seen hopping on three legs and was not able to keep up with her pack.

Researchers working with toe-clipped small mammals have indicated that toe removal did not hinder movements. Baumgartner (1940) found that the removal of one toe per foot did not impede the arboreal activities of fox squirrels (Sciurus niger). Dell (1957) toe-clipped varying hares and noted no complications or infection. Ambrose (1972) concluded that toe-clipping meadow voles did not increase predation by a barn owl (Tyto alba). Blair (1941:153), in his review of techniques for studying small mammals stated, "I know of no case in which an animal died or appeared ill from the effects of toe clipping."

Individual tracks or trails of coyotes with missing toes were observed on 21 occasions. Fifteen separate tracks were located in soft soil. On three occasions tracks of suspected damaging coyotes were found in the immediate vicinity of predator-killed turkeys. Six trails of toe-clipped coyotes were identified in snow; three permitted snow-tracking a marked coyote, accompanied by a second adult coyote, 11 km during 3 days. Unusually light snowfall during the winter of 1975-76 hindered effective snow-tracking.

Coyotes tracked in snow often placed a rear foot in the track left by a front foot. This hindered the identification of tracks made by coyotes with toes missing from front feet. For this reason, we believe it would be preferable to remove toes from the hind feet.

Toe removal may be a useful tool in studying canids and other mammals, especially when combined with snow-tracking or radio telemetry.

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SEASONAL MOVEMENTS OF COYOTES IN THE GREAT PLAINS[1]

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Abstract: Home range, activity, and movements of coyotes were determined with radio-telemetry during six physiologically defined seasons (breeding, gestation, nursing, pup training, adolescence, and pre-breeding) in southeastern Nebraska from May 1975 through August 1976. Average home range sizes of adult coyotes during the breeding, gestation, nursing, and pup training seasons were approximately equal, but tended to increase during the adolescent and pre-breeding seasons. Total home ranges of adult males and females averaged 36.7 and 33.8 km^2,

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respectively. A yearling female's home range was 134.5 km^2. Coyotes were usually active from sunset until approximately 1 hour after sunrise. Average distance traveled during 24-hour periods was greater for female (12.06 km) than male (10.20 km) adults or a yearling female (10.42 km). Longest average distances traveled were recorded during pre-breeding and breeding seasons.

Little information is available concerning movements of coyotes in the Great Plains. Home ranges of coyotes have been documented by snow-tracking in Minnesota (Stebler 1951, Ozoga and Harger 1966) and radio-telemetry in Arkansas, Minnesota, and Arizona (Gipson and Sealander 1972, Chesness and Bremicker 1974, Danner 1976). Limited information on daily movements of coyotes has been reported (Chesness and Bremicker 1974, Danner 1976). Ozoga (1963), Gipson and Sealander (1972), and Chesness and Bremicker (1974) presented information on the activity of coyotes. Andelt and Mahan (in prep.) studied home range and activity of an urban coyote. Earlier studies did not consider coyote movements with respect to the biological seasons of coyotes.

This paper presents radio-tracking information on home range, activity, and daily movements of coyotes during six physiologically defined seasons in an intensively farmed and hunted section of the Great Plains from May 1975 through August 1976.

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trapping suggestions; and J. L. Allison for typing the manuscript.

STUDY AREA

The study was conducted on the University of Nebraska Agricultural Field Laboratory and adjacent areas in southeastern Saunders county near Mead and in eastern Lancaster and western Cass counties near Waverly, Nebraska. The climate during the last 40 years was characterized by cold winters (daily minimum temperatures during January average -11.3° C) and warm summers (daily maximum temperatures during July average 31.6° C). Precipitation averages 67.7 cm which included approximately 63.5 cm of unmelted snowfall (National Oceanic and Atmospheric Administration 1975).

Topography of both study sites consisted of low rolling hills with some gently sloping upland and bottom-land areas. Both sites were located in intensively farmed areas with rowcrops of grain sorghum, corn, and soybeans; small grains of wheat and oats; forage crops of brome grass, alfalfa, and native grasses; and creek bottoms and fence rows of woody vegetation.

MATERIALS AND METHODS

Coyotes were captured with snares or number 3 steel traps with offset jaws. Each coyote was toe-clipped (Andelt 1976) to facilitate snow-tracking and to determine their presence at poultry and livestock loss sites. Coyotes were outfitted with 151 MH_z radio-telemetry collars. Most collars were wrapped with bright-colored tape (#471 lane marking tape, Minnesota Mining and Manufacturing, St. Paul, Minn.) to permit visual identification. Radio signals were received

on a portable receiver (Model LA-12, AVM Instrument Company, Champaign, Ill.) connected to a car-top mounted null-peak antenna system or a portable four element yagi antenna.

Radio locations (fixes) were determined by triangulation using one vehicle. Bearings were taken from one station and the vehicle was quickly driven to another station where the second bearing was taken. Coyotes were usually located weekly by ground or aerial radio-tracking. In addition, each coyote was located once a month at 1-hour intervals throughout a 24-hour period from May 1975 to July 1976. A mated pair was intensively monitored during evening hours from late June to Mid-August 1976.

Biological seasons of the coyote were determined in consultation with Dr. H. T. Gier from overall activities of coyotes throughout the year (Table 1). Home range, activity, and movements of the study coyotes were analyzed according to these seasons.

Home ranges were determined from radio-locations, snow-tracking, visual sightings, capture sites and locations where study coyotes were killed. Biological season and total home ranges were determined by the ellipse method (Gipson and Sealander 1972), and the minimum area method (Mohr 1947) was also used to calculate total home ranges. Random movements outside established ranges and side ranges were not included in the analysis of home range, but are presented in the home range estimate for comparison to other studies (Table 2). Daily distances traveled were determined by adding the straight line distances traveled between consecutive hourly radio fixes during a 24-hour period and by the first and last location of a 24-hour period.

Periods of activity were determined by averaging distances traveled during hourly intervals. This distance was used as an index of the relative amount of activity.

The above calculations were made with an IBM 360 computer using programs developed at the University of Arkansas and the University of Nebraska. Home range ellipses were drawn by a Cal-Comp plotter.

RESULTS

Fourteen coyotes were captured and outfitted with radio-transmitters. Over 2100 locations provided information for a seasonal analysis of movements of 10 coyotes (Table 2). Coyotes 1, 2, and 9 were monitored at the University field laboratory and coyotes 4, 5, 11, 12, 13, 14, and 16 were monitored at the Waverly study site.

Home Range

The average home range size of male and female adults differed little during breeding, gestation, nursing, and pup training periods, increased slightly during adolescence, and approximately doubled during pre-breeding (Table 2). There was little difference between the average home range of adult males and adult females within each biological season except adolescence when males tended to have larger ranges than females. Average total home ranges of adult males and adult females were also similar (Table 2).

Home ranges varied little within adult males and adult females during most biological seasons as indicated by small standard deviations (Table 2). A large standard deviation (14.3) was noted for adult males during the nursing period. The home range of males

1, 2, 4, and 11 were approximately the same size (10.5 to 15.9 km^2), but the range of 16 was larger (44.3 km^2). Data indicated males 1, 2, and 11 probably had mates while male 16 appeared to be a wanderer not involved in pup rearing activities.

Home range of yearling female 12 (Table 2) was larger than the ranges of all adults monitored during the same biological seasons (breeding, gestation, nursing, and pup training). Data indicated female 12 was a wanderer, had no mate, and did not raise pups.

Temporal overlap of adult male or adult female home ranges was not evident, but some male ranges overlapped female ranges (Figs. 1, 2, and 3). Males 1 and 2 and female 9 were monitored during the same period at the University field laboratory. The ranges of males 1 and 2 overlapped slightly but male 1 totally overlapped the range of female 9. Both 1 and 9 were found together in and near a sheep pen on 23 September 1975 where a dead ewe suspected of being killed by coyotes was later found (Andelt and Gipson, in prep.). The signal produced by female 9's transmitter decreased in strength shortly after, making it difficult to locate her. The exact relationship of female 9 and male 1 was not determined, but we suspect they were mates.

The capture site of male 2 was within the range of male 1. Since male 2 was not relocated within the range of male 1 during the next 8 months, we considered the capture site a exploratory movement outside male 2's range and did not consider it in the home range analysis (Fig. 1). Male 2 was located approximately 5.2 km south of his former range from 24 to 30 December, but was located in or near his former range from 11 January until he was shot on 2 February. The area traversed

was considered a side range and was not used in the home range analysis. Male 1 was located 8.1 km NNE of his former range on 26 November and was shot by a hunter 3.3 km south of his former range on 30 November. These locations were considered exploratory movements outside his range and were not used in the home range analysis. The locations of males 1 and 2 outside their home range are plotted in relation to their home range ellipse in figure 1.

The home ranges of male 4 and female 5 were determined during the 1975 nursing period (Fig. 2). Female 5 was also monitored during the next five biological seasons. She was approximately 13.5 months old when captured and did not have pups. Her range was approximately 10.4 km^2 during the nursing, pup training and adolescent periods. She was located outside this range on 29 September and during November. The locations outside her range were considered exploratory movements and were not used in the home range analysis. She explored and settled in another range in early December, her new range appeared to stabilize during breeding and gestation. Her center of activity (Hayne 1949) during gestation 1976 was 10.7 km north of her activity center during nursing 1975. This shift in home range was the only evidence of "dispersal" in our study. Her second home range was used in the analysis of total home range size. The first home range was considered a pre-dispersal range and was not used in the analysis of total home range size but was used for the seasonal analysis.

The home range of yearling female 12 temporally overlapped the ranges of coyotes 11, 13, 14 and 16. Yearling 12 and female 13 were often found in the same 65 ha native grass field during breeding,

gestation, and nursing seasons, but no overlap was noted during pup training 1976. Female 13 was shot on 6 November and her reproductive tract contained placental scars from the last 2 years; yearling 12 was probably female 13's pup. Yearling 12's range overlapped the range of male 16, but they were never located together. Yearling 12 was often located around the ranges of 11 and 14, but only five locations were within the edge of their ranges.

Home ranges of male 16 and female 13 overlapped, but they were located near each other on only one occasion, we suspect they were not mates. Male 11 and female 14 were mates and their home ranges were almost identical during the gestation, nursing and pup training periods.

Coyotes 11 and 14 often moved around the edge of their home ranges. Coyotes 1 and 2 also appeared to move around the edge of their ranges during nursing and pup training periods. Possibly these coyotes were defending or reinforcing their ranges.

The ellipse and minimum area methods were used to calculate total home range sizes of study coyotes (Table 2). The average home range estimated by the ellipse method (45.3 km^2) was 134 percent larger than that estimated by the minimum area method (33.8 km^2). Home range sizes were also calculated using all locations including exploratory movements, side ranges, and pre- and post-dispersal ranges for comparison to earlier studies. Total home ranges averaged 45.3 km^2 when exploratory movements, side ranges, and home range shifts were not used in the analysis, but averaged 80.1 km^2 when those perameters were used. This represents a 177 percent difference in the two methods. The average of all individual biological season home ranges (28.3 km^2) was 56 percent

of the average total home range (45.3 km^2).

Activity

Combined activity patterns of all coyotes were quite similar during each of the six biological seasons (Fig. 4). Coyotes were usually active from sunset until approximately 1 hour after sunrise, but some were often found at the same location for 1 or more hours. Little movement was recorded during daylight. Activity patterns of adult males, adult females, and a yearling female were similar (Fig. 5) although adult females appeared to be more active than adult males from 2230 to 0130. The yearling female was slightly more active during daylight and slightly less active from 2130 to 2330 than adults.

Two extreme activity patterns were shown for female 5 during the breeding and gestation periods (Fig. 6). During breeding (Fig. 6A) she ran 4.4 km from 2400 to 0100, one of the greatest distances measured for any coyote between hourly fixes. During one night of the gestation period (11-12 March) female 5 was monitored from 1100 to 1100 (Fig. 6B). A winter storm front arrived at the study area at 0250; average hourly winds of 42.6 to 55.6 km/hr. from the northwest blew throughout the rest of the tracking shift and the temperature fell to -7° C. Female 5 was inactive from 2300 to the end of the tracking shift. Other coyotes, monitored during snow and rain, did not appear to alter their activities.

Daily Movements

The straight line distances traveled by coyotes during 45 twenty-four hour tracking shifts are graphed in Figure 7. The

distance traveled by coyotes based on consecutive hourly locations was quite variable for each coyote from one tracking shift to another as well as from one coyote to another when tracked during the same period. The shortest distance traveled was 3.96 km by male 4 during the pup training period. The longest distance traveled, 20.45 km, was by male 2 during the pre-breeding season.

The average distance traveled by adult females was greater than adult males during all six biological seasons. The total average distance traveled by adult females was 12.22 km compared to 10.31 km by adult males and 10.45 km by a yearling female. Mates 11 and 14 were also simultaneously located 8 to 12 times during each of 13 evenings from 28 June through 14 August, female 14 moved a greater average distance (8.5 km) than male 11 (6.7 km).

The least amount of movement for all coyotes combined was measured during the gestation period, slightly more movement occurred during the nursing and pup training period, and progressively more movement was evident during adolescence, pre-breeding, and breeding. More movement occurred in January than in December of the pre-breeding season (Fig. 7).

Distances traveled were also calculated between the first and last locations of 24-hour tracking shifts (Fig. 7), used by some researchers to describe daily distance traveled. The distance between these daily rest sites varied from 0.02 to 5.63 km. The average distance between rest sites of adult males was greater than for females in all seasons except gestation. Daytime retreats were closer during breeding, nursing, and pup training than during gestation and pre-breeding;

they were farthest apart during the adolescent period.

The average distance traveled by all coyotes during 45 tracking shifts based on the first and last locations (1.65 km) was 15 percent of the total distance traveled based upon consecutive hourly locations (11 km).

DISCUSSION

Biological Seasons of the Coyote

The annual physiological cycle of coyotes is tied closely to reproductive activities. Six biological seasons (breeding, gestation, nursing, pup training, adolescence, and pre-breeding) were defined based on estimates of average dates for the population to change from one season to another. During our study, coyote foods were in short supply, thus delaying reproduction 1 to 2 weeks (H. T. Gier, personal communication). In years of abundant food, all biological seasons would be 1 to 2 weeks earlier than designated below. Most transitions between biological seasons are gradual, and overlap between individuals may span several weeks.

Breeding, 1-29 February. Data presented by several researchers indicate breeding normally occurs during the month of February (Young and Jackson 1951, Wade 1973). Gier (1968:44) found the average date of ovulation for Kansas coyotes was approximately 25 February from 1948 to 1954 and stated that estrous in the coyote lasts 10 to 30 days and ends about 3 days after ovulation. Bekoff and Diamond (1976) observed a male coyote spending more time sniffing and licking a female's vulval area during early February. During the breeding

season a strong bond exists between mated pairs, males and females are seldom found apart (H. T. Gier, personal communication).

Gestation, 1 March through 30 April. The gestation period lasts approximately 60 days (Young and Jackson 1951, Gier 1968). Gipson et al. (1975) reported conception in Arkansas coyotes ranged from 16 February to 7 March and parturition from 20 April through 8 May. These data suggest an approximate gestation period from 1 March to 30 April. During the gestation period the male and female hunt together, sleep near each other, and in late pregnancy the male frequently hunts alone and brings food to his mate (Gier 1975).

Nursing, 1 May through 30 June. A pup nursing period of approximately two months follows gestation. Young and Jackson (1951), Wade (1973), and Gier (1975) indicate pups remain near the den for approximately two months after parturition. During this period, mated coyotes are involved with pup care and probably spend considerable time near the den.

Pup training, 1 July through 15 September. The den is abandoned in late June or early July and pups are given survival training by the adults (Gier 1975) for approximately 2.5 months (H. T. Gier, personal communication). During this biological season pups probably go on increasingly longer forays with the adults. Home range centers of adults may shift from dens to new sites where their pups congregate for loafing and play.

Adolescence, 16 September through 15 November. A period of increasing pup independence lasts for about two months until pups disperse from their natal ranges. Gier (1975) indicated that many

family units remain together until November; he noted that November and December are months of wandering for juvenile coyotes. Knowlton (1972) indicated that infiltration into new areas in Texas became important in November, increased through January, and then decreased through March. Chesness and Bremicker (1974) found most pups dispersed during mid- and late November and remained as loners throughout the winter and often remained as roaming yearlings. Nellis and Keith (1976) reported dispersal of young coyotes in Minnesota apparently started in October and some coyotes did not disperse until late in their first year or possibly their second year. Observations by Ryden (1975) suggest that some pups may remain in the vicinity of their parents and maintain social bonds.

Pre-breeding, 16 November through 31 January. This is a period when adults are free from pups and become increasingly attracted to one another (H. T. Gier, personal communication). Bekoff and Diamond (1976) observed that the urine of a female coyote became increasingly interesting to males in late November. With freedom from the pups adults probably range over larger areas.

Home Range

The size of coyote home ranges in our study was influenced by the time of year, length of time on the air, their reproductive state, and method of estimating home ranges. Home ranges were approximately equal during breeding, gestation, nursing, and pup training, but increased in size during adolescence and pre-breeding. Camenzind (1974) indicated home ranges of coyotes in northwestern Wyoming varied on a seasonal

basis and were larger during winter than summer and the two areas did not always coincide. Since prey populations were at their lowest level during the breeding season of the coyote while coyote home ranges tended to stabilize and were small, we believe home ranges are influenced more by the reproductive drive than food.

Home ranges calculated during each of the six biological seasons were 56 percent of the average total home range size indicating home ranges increase with duration of monitoring. Hibler and Knowlton (1974) suggested 150 relocations over a period of 3-4 months may be essential to adequately describe areal utilization. Gipson and Sealander (1972) monitored coyotes for shorter periods of time and calculated smaller home ranges than had been determined in other radio-tracking studies; larger ranges may have been determined if coyotes had been monitored for longer periods. The mated pair and other coyotes suspected of being mated and involved in raising pups had rather small and stable home ranges during the breeding, gestation, nursing, and pup training periods while unmated coyotes appeared to have larger ranges.

Home range was influenced by the estimation method. The elliptical method gave an average total home range size 134 percent larger than the minimum area method for our study coyotes. In another study, home ranges estimated by the ellipse method gave an area 140 percent larger than the minimum area method (calculated from Danner 1976). Home ranges were increased by 177 percent when exploratory movements, side ranges, and home range shifts were considered in the analysis. When comparing home ranges, the same method of estimation should be used. In the following comparison of our home ranges to those calculated

by previous investigators, the same method of estimation was used.

The average total home range of adult males and adult females in our study was similar to those obtained with telemetry in Arizona (Danner 1976). Chesness and Bremicker (1974) estimated similar home ranges of adult males in Minnesota, but females tended to have much smaller home ranges calculated by the minimum area method (16.3 km^2). Gipson and Sealander (1972) estimated smaller home ranges for adult males (33.2 km^2) and adult females (13.2 km^2) by the ellipse method than estimated in our study. Stebler (1951) and Ozoga and Harger (1966) estimated home ranges of 44 and 52 to 129 km^2, respectively, in Minnesota by snow-tracking. A yearling male located in southern Lincoln, Nebraska had a smaller home range (7.4 km^2) during periods covering late gestation, nursing and early pup training (Andelt and Mahan, in prep.) than did our study coyotes.

Temporal overlap of adult male or adult female home ranges in our study was not evident although male and female ranges overlapped. The home range of a yearling female overlapped the range of an adult female who was probably her mother. She also overlapped the range of an adult male and encompassed the range of a mated pair, but only five locations were within the edge of the pair's range. Chesness and Bremicker (1974) noted adult female ranges did not overlap, but adult males tended to overlap. They also noted that adult males tended to be highly mobile. Gipson and Sealander (1972) noted a large amount of overlap in adult male ranges and adult female ranges, but most of this overlap was not temporal (recalculated from their data); the ranges of two adult males overlapped while being monitored during the

same period. Danner (1976) found considerable overlap of adult female home ranges, and pup and yearling ranges.

Exploratory movements outside former ranges in our study were detected particularly during November and December. An adult female began exploring new areas during November and located in a new range during December. Two males moved out of their former ranges during late November and December, but were later located within or near their former ranges. During this period, coyote home ranges appeared variable and were not well defined.

Activity

Activity patterns of coyotes in Nebraska were similar to those reported in Minnesota (Ozoga 1963, Chesness and Bremicker 1974). During all six biological seasons coyotes became active at sunset and generally remained active throughout the night with the possible exception of the pup training season when coyotes appeared to become active 1 to 2 hours before sunset. Activity usually ceased 1 to 2 hours after sunrise and coyotes generally remained inactive throughout daylight. In contrast, Gipson and Sealander (1972) reported coyotes often foraged during the day although they were most active during the night.

Chesness and Bremicker (1974) noted activity was most intense during early night and early morning hours. Coyotes in Nebraska were not more active during early morning and early evening hours than during the rest of the night with the possible exception of pre-breeding and breeding seasons. Ozoga (1963) found most coyotes snow-tracked in Michigan bedded from 1000 to 1700 and in summer they were more active during the day. The activity of an urban coyote in Lincoln, Nebraska

was most intense during early and late nights (Andelt and Mahan, in prep.). Natural selection may favor diurnal activity in an intensively hunted area like southeastern Nebraska.

Daily Movements

Distances traveled during 24-hour periods based upon consecutive hourly readings averaged 11.0 km for Nebraska coyotes. The greatest distance recorded was 20.5 km. Chesness and Bremicker (1974) estimated the distances traveled by Minnesota coyotes was 4.8 km based upon at least 12 radio-locations during a 24-hour period during fall and early winter. While snow-tracking, they estimated distances traveled during winter average 4.0 km. Gipson and Sealander (1972) reported the greatest distance traveled by a coyote in Arkansas in 6 hours was 12.9 km.

The daily distances traveled by Nebraska coyotes based upon the first and last locations of 24-hour tracking shifts was comparable to distances traveled between daily fixes for Minnesota coyotes by Chesness and Bremicker (1974) who indicated these distances were minimum daily movements. Our data were comparable to Danner's (1976) for adult males and juvenile females in Arizona, but our adult females were not located as far away from the previous day's location (1.2 vs. 4.6 km). Since the distance traveled based upon our first and last locations of 24-hour tracking shifts was 15 percent of the distance traveled during consecutive hourly locations, distances traveled based upon consecutive daily locations are a gross underestimation of distances traveled during 24 hours.

The average distance traveled during tracking shifts was greatest

during the pre-breeding and breeding seasons. This was probably in response to increased reproductive activity and/or diminishing food supplies.

Average distance traveled during 24-hour tracking shifts was greater for adult females than for adult males during all six biological seasons even though males had larger home ranges. Knowlton (1972) noted that during spring a greater proportion of males than females were recovered from standard coyote getter lines in high density areas and concluded that males predominate, presumably as a result of limited activity of gravid females. Our data indicated distances traveled even during gestation and nursing were greater for two mated females than for a mated male.

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Fig. 1. Home range ellipses of adult male coyotes 1, 2, and adult female 9 monitored at the University Field Lab showing little temporal overlap in home ranges of males and overlap of a male with a female. EM1, exploratory movements of male 1 during November; EM2, exploratory movement of male 2; and SR2, side range of male 2 during December.

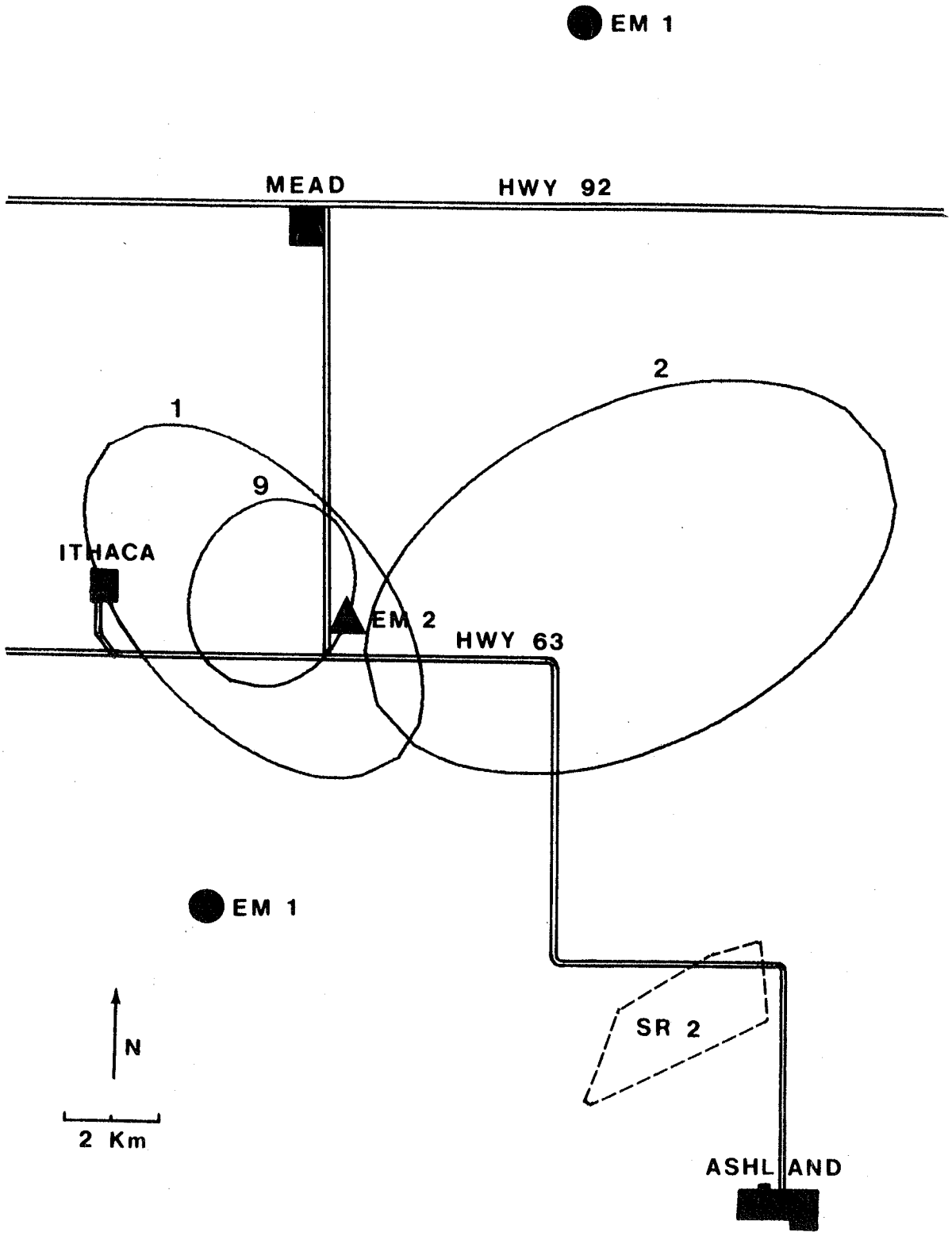

EM 1
MEAD
HWY 92
2
1
9
ITHACA
EM 2
HWY 63
EM 1
N
2 Km
SR 2
ASHLAND

Fig. 2. Home range ellipses of adult female 5 before "dispersal" and male 4 determined during 1975 at the Waverly study site. EM5, exploratory movements of female 5 during September and November.

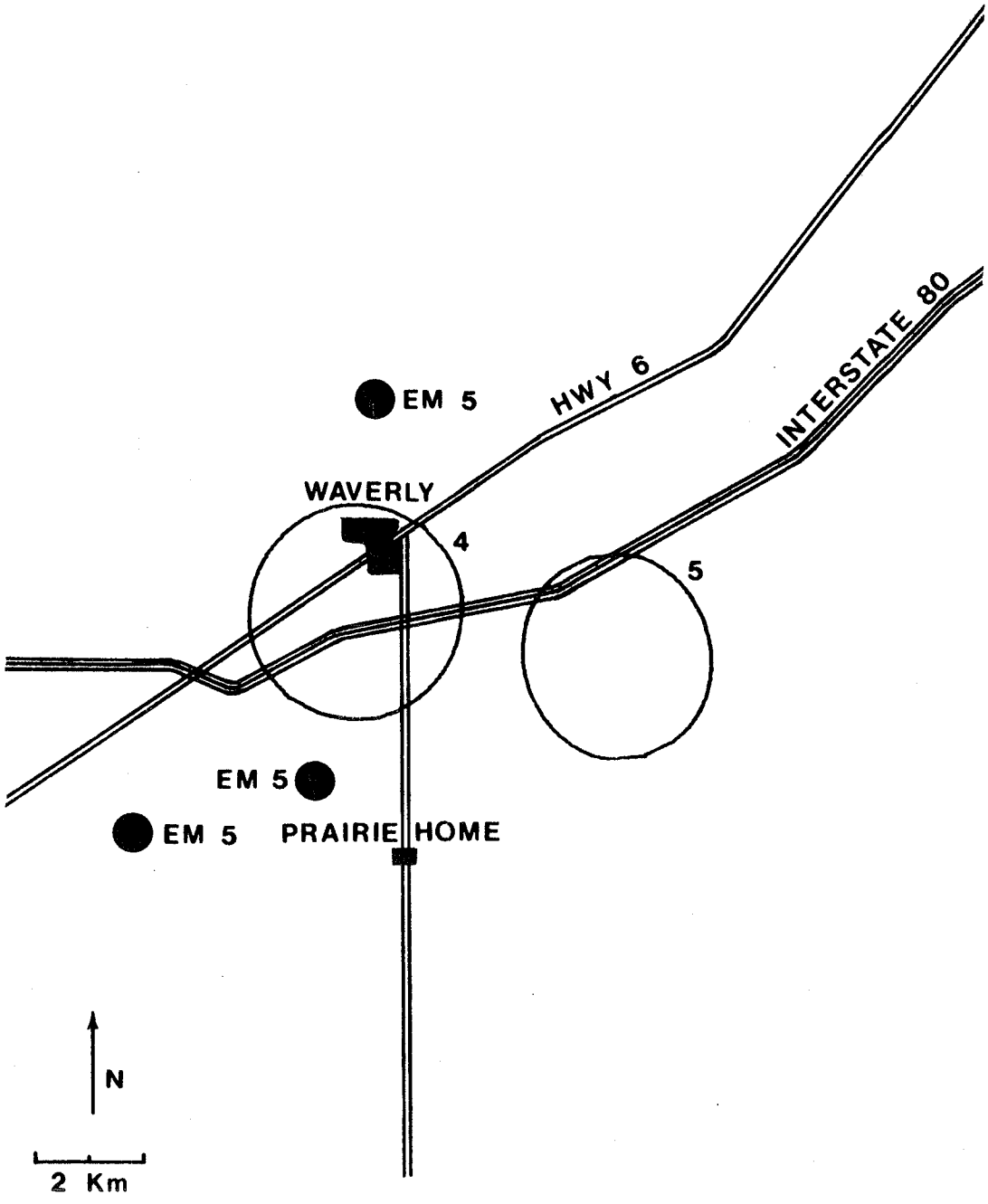

EM 5
HWY 6
INTERSTATE 80
WAVERLY
4
5
EM 5
EM 5
PRAIRIE HOME
N
2 Km

Fig. 3. Home range ellipses of adult female 5 after "dispersal", adult females 13 and 14, adult males 11 and 16, and yearling female 12 determined during December, 1975 and 1976 at the Waverly study site showing overlap of adult male and adult female home ranges and non-overlap of male or female ranges.

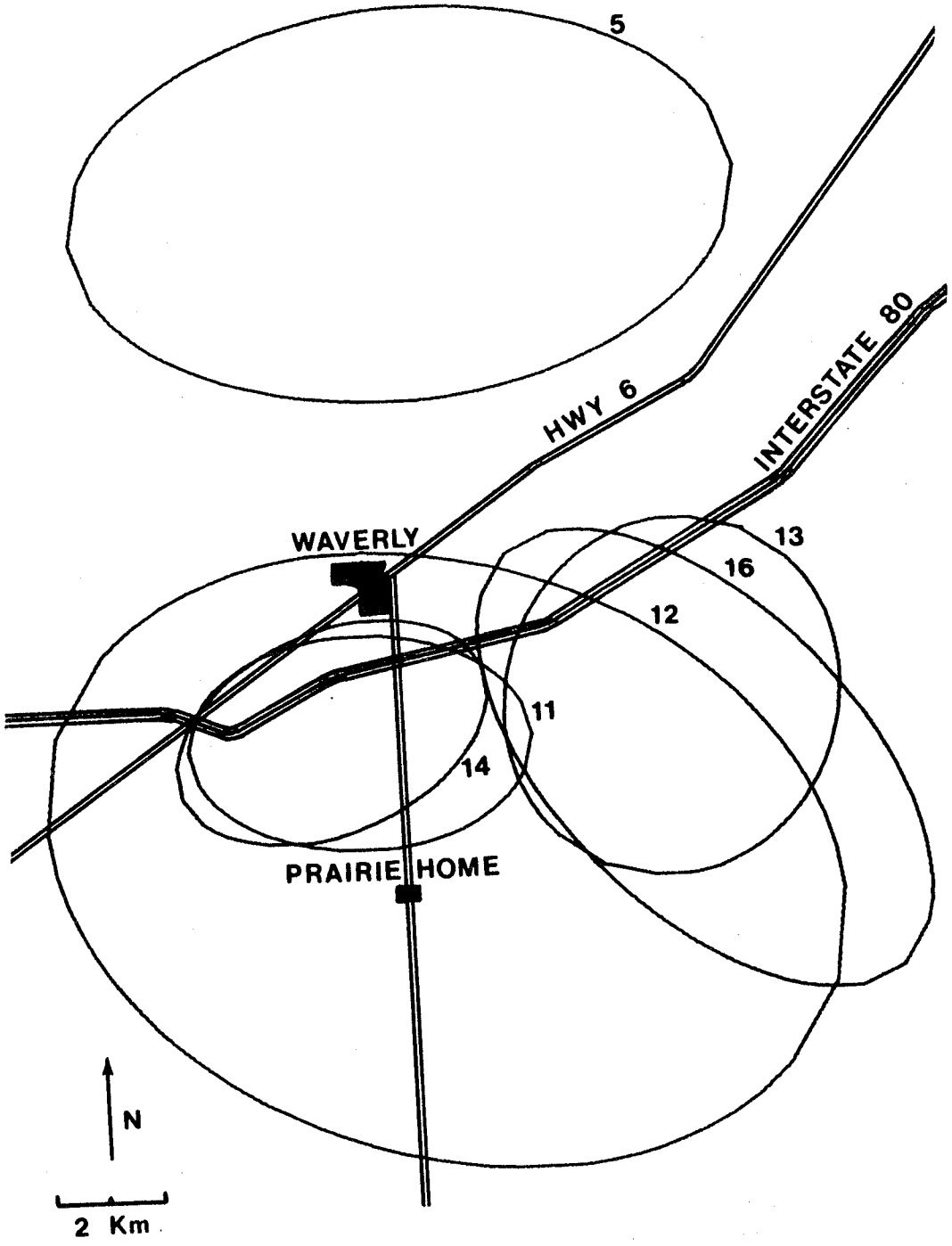

5
HWY 6
INTERSTATE 80
WAVERLY
13
16
12
11
14
PRAIRIE HOME
N
2 Km

Fig. 4. Combined activity of all coyotes during six biological seasons of the coyote showing nocturnal movements. Arrows indicate approximate time of sunrise and sunset.

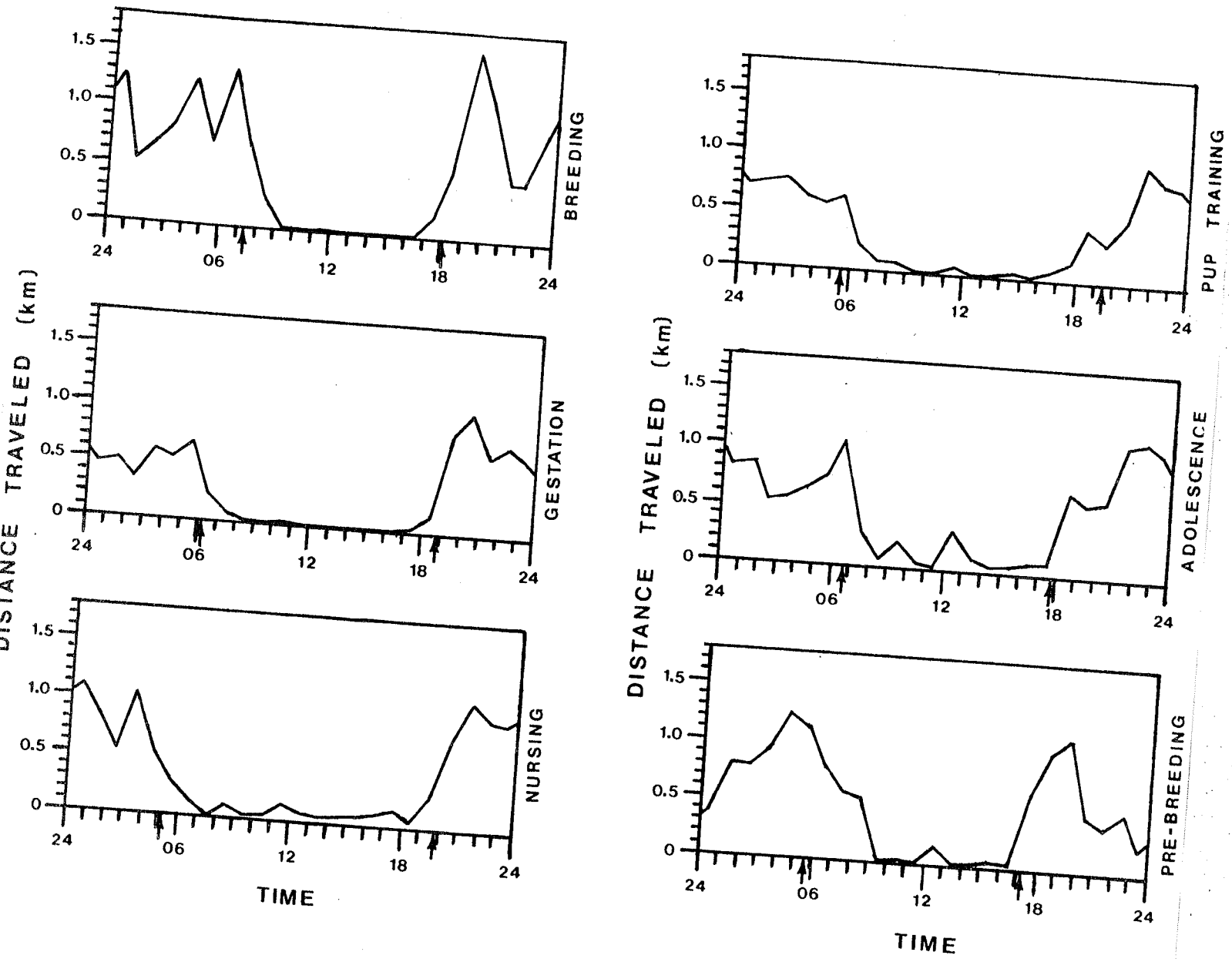

DISTANCE TRAVELED (km)
1.5
1.0
0.5
0
24
06
12
18
24
BREEDING
GESTATION
NURSING
TIME
PUP TRAINING
ADOLESCENCE
PRE-BREEDING

Fig. 5. Comparison of activity patterns of adult males, adult females, and a yearling female.

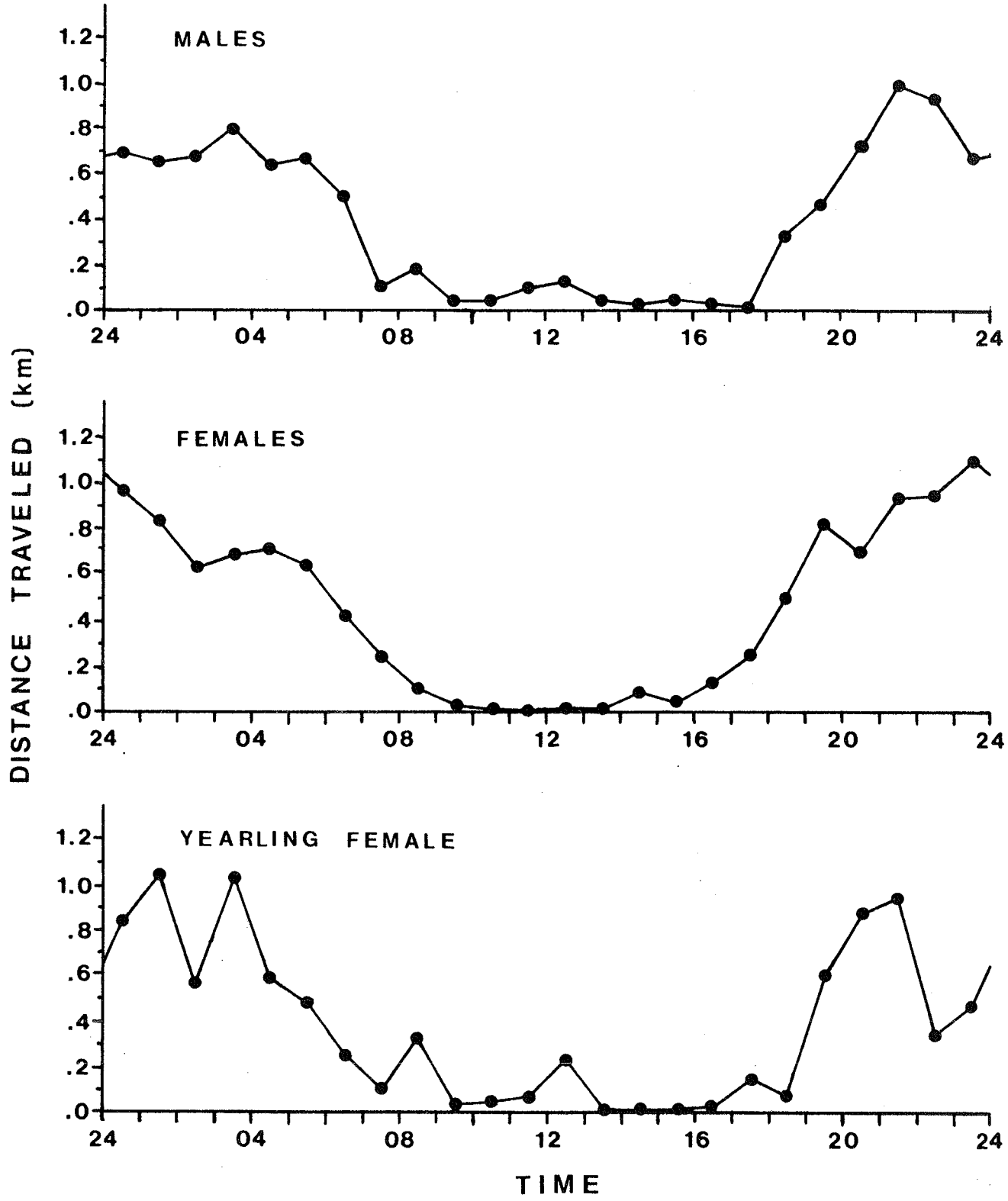
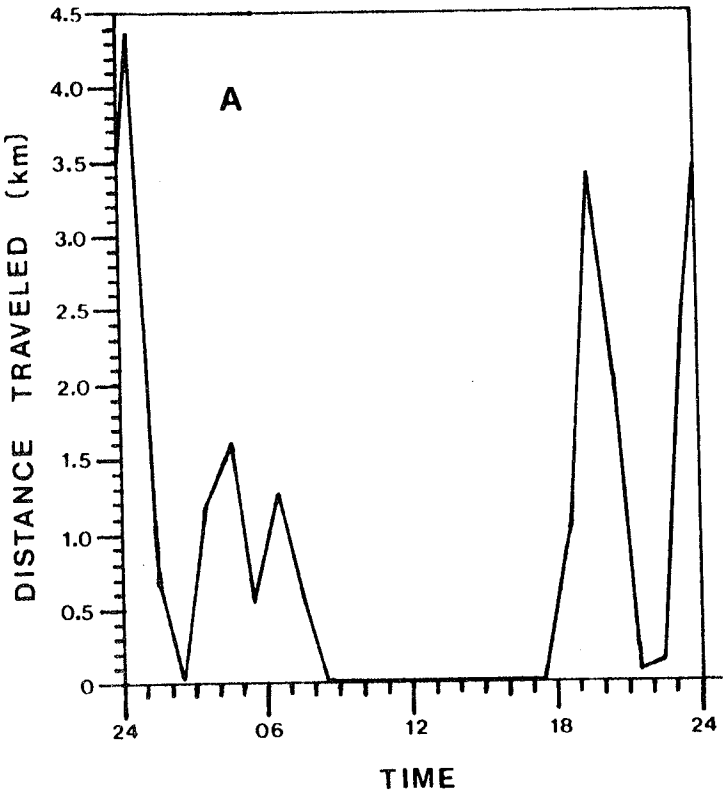

MALES
FEMALES
YEARLING FEMALE
DISTANCE TRAVELED (km)
1.2
1.0
.8
.6
.4
.2
.0
24
04
08
12
16
20
24
TIME

Fig. 6. Extreme activity patterns of female 5; A, movements monitored during a 24-hour period of the breeding season; B, limited nocturnal activity during a winter storm.


A
DISTANCE TRAVELED (km)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
24
06
12
18
24
TIME

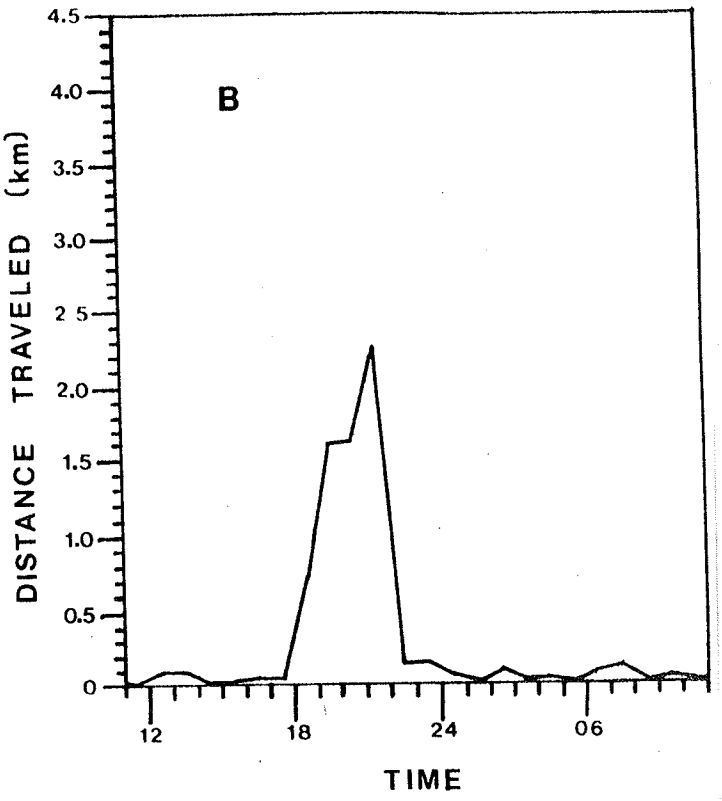

B
DISTANCE TRAVELED (km)
4.5
4.0
3.5
3.0
2 5
2.0
1.5
1.0
0.5
0
12
18
24
06
TIME

Fig. 7. Comparative daily distances traveled by male and female adult coyotes and a yearling female during six biological seasons based upon the combined distances between 23 to 25 consecutive hourly locations and the distance between daily rest sites (locations 24 hours apart).

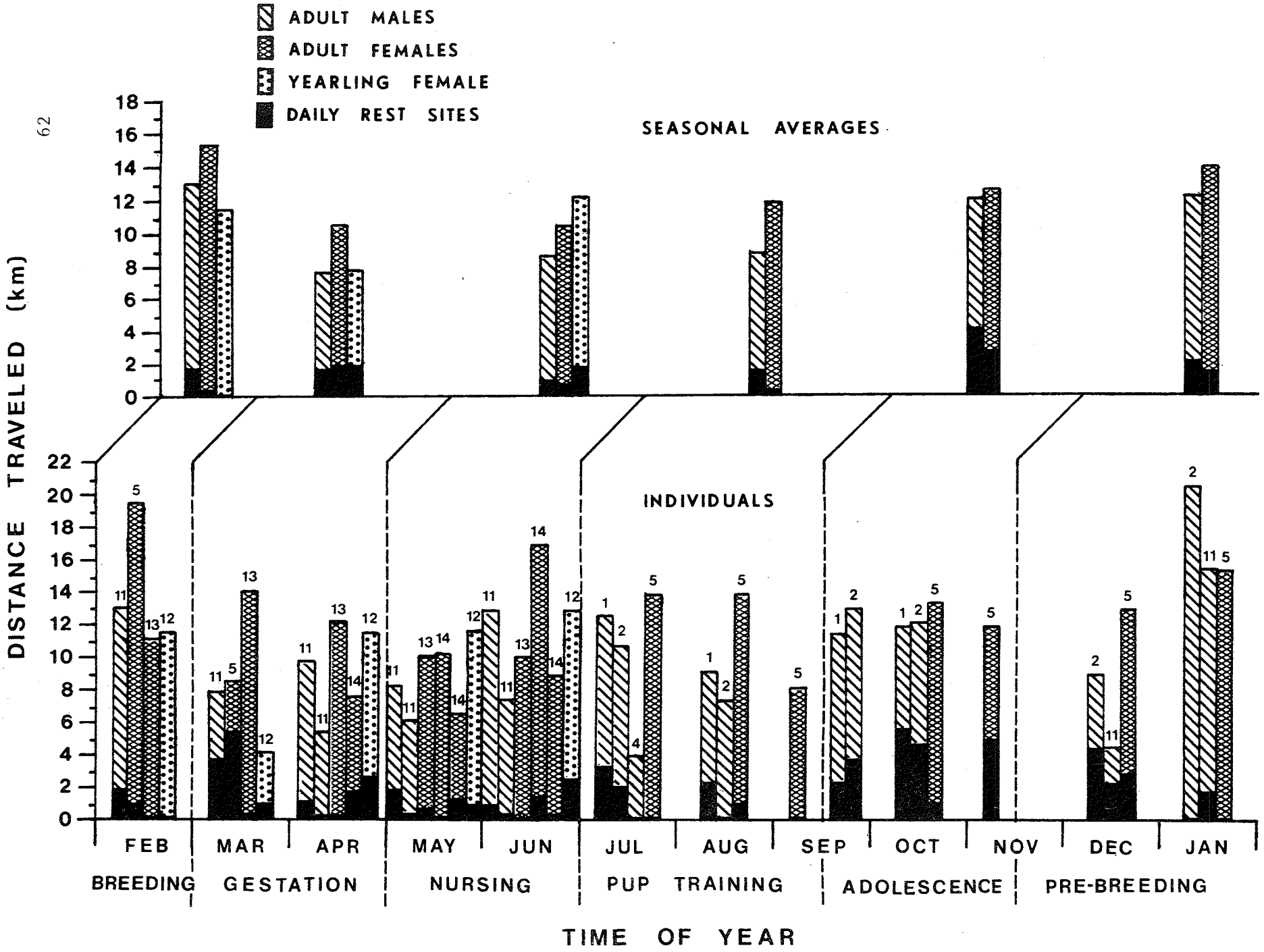

ADULT MALES
ADULT FEMALES
YEARLING FEMALE
DAILY REST SITES
SEASONAL AVERAGES
INDIVIDUALS
DISTANCE TRAVELED (km)
TIME OF YEAR
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
BREEDING
GESTATION
NURSING
PUP TRAINING
ADOLESCENCE
PRE-BREEDING

Table 1. Biological seasons of the coyote.

Season	Time Span	Characterization
Breeding	February	Copulation, ending with conception
Gestation	March-April	Conception to parturition, den preparation
Nursing	May-June	Parturition to solid food
Pup training	July - 15 September	Survival training by adults
Adolescence	16 September - 15 November	Pups increasingly independent, attain mature stature, family may remain loosely associated
Pre-breeding	16 November - January	Adults independent of young, gonadal development to breeding condition

Table 2. Periods monitored, seasonal home ranges, and a comparison of total home range sizes calculated by the ellipse and minimum area methods.

Coyote	Period Monitored	Locations No.	Locations Days	Home Range Size: Ellipse, by biological season: Br.	Ges.	Nur.	P.T.	Ado.	Pre-Br.	Total: Ellipse	Total: Min. Area
Adult males											
1	11 May-30 Nov	214	44			15.9	23.5	30.6	--- (100.9)[a]	35.8 (154.3)	27.8 (105.5)[a]
2	27 May- 2 Feb	238	51			10.9	18.4	26.9	35.5 (120.9)[a]	66.5 (143.8)[a]	45.0 (107.8)[a]
4	10 Jun- 9 Jul	34	14			10.5				12.8	8.9
11	3 Dec-14 Aug	482	90	9.6	11.4	14.0	10.9		15.4	20.4	17.6
16	18 Apr-10 Jul	63	18			44.3				48.0	44.6
			MEAN	9.6	11.4	19.1	17.6	28.8	25.5 (79.1)[a]	36.7 (75.8)[a]	28.8 (56.9)[a]
			S.D.			14.3	6.3	2.6	14.2 (56.0)[a]	21.5 (68.3)[a]	16.1 (47.3)[a]
Adult females											
5	12 Jun-20 Mar	282	74	26.1	13.0	2.6	8.7	5.5 (64.6)[a]	46.9	72.9 (225.0)[a]	54.7 (173.6)[a]
9	12 Sep-10 Jul	41	18					6.0		11.0	8.8
13	23 Jan-14 Aug	213	72	12.7	14.8	16.8	7.7			33.3	22.3
14	4 Apr-14 Aug	353	55		13.6	15.5	12.6			18.0	16.1
			MEAN	19.4	13.8	11.6	9.7	5.8 (35.3)[a]	46.9	33.8 (71.8)[a]	25.5 (55.2)[a]
			S.D.	9.8	0.9	7.9	2.6	0.4 (41.4)[a]		27.7 (102.5)[a]	20.2 (79.1)[a]

Yearling female										
12	20 Jan-14 Aug	209	58	50.6	67.1	125.5	85.6		134.5	92.6

[a]home range size calculated with all locations including exploratory movements and side ranges.

COYOTE RELATIONSHIPS TO DEN SITES AND INTERACTIONS OF A MATED PAIR

William F. Andelt and Philip S. Gipson

ABSTRACT.—Coyote relationships to den sites and the interactions of a mated pair were documented with radio-telemetry in southeastern Nebraska during 1976. Coyote proximities to den sites decreased from pre-breeding through breeding and nursing periods; both sexes were closely associated with den sites. Strong pair bonds were evident in a mated pair from late January through October.

Information on the proximity of coyotes to den sites and the spatial relationships of mates is mostly fragmentary. Ryden (1975) described the social behavior of coyotes in a protected area, the National Elk Refuge in northwestern Wyoming. Fichter (1950) presented limited information on coyote activities at den sites in Nebraska. This paper presents data on the relationships of coyotes to den sites and the interactions of a mated pair in an intensively hunted section of the Great Plains.

STUDY AREA

The study was conducted in eastern Lancaster and western Cass counties near Waverly, Nebraska. The area was characterized by a typical Great Plains climate of cold winters and warm summers. During the past 40 years precipitation averaged 67.7 centimeters (cm) including 63.5 cm of unmelted snow (National Oceanic and Atmospheric Administration, 1975).

Topography of the study site consisted of low rolling hills with

some gently sloping upland and lowland areas. The study area was intensively farmed with rowcrops of grain sorghum, corn, and soybeans; small grains of wheat and oats; forage crops of brome grass, alfalfa and native grass; and creek bottoms and fence rows of woody vegetation.

MATERIALS AND METHODS

Coyotes were captured with snares or number 3 steel traps with offset jaws. Each coyote was toe-clipped (Andelt, 1976) to facilitate identification of individuals while snow-tracking and to determine their presence at poultry and livestock loss sites. Coyotes were outfitted with 151 MH_Z radio-telemetry collars. Most collars were wrapped with bright-colored tape (#471 lane marking tape, Minnesota Mining and Manufacturing, St. Paul, Minn.) to permit visual identification. Radio signals were received on a portable receiver (Model LA-12, AVM Instrument Company, Champaign, Ill.) using a car-top mounted null-peak antenna system or a portable four element yagi antenna.

Radio locations (fixes) were determined by triangulation using one vehicle. Bearings were taken from one station and the vehicle was quickly driven to another station where the second bearing was taken. Fixes on a mated pair were often taken from the same two tracking stations; at other times, one coyote was located from two stations, then the other coyote was quickly located from other stations. Generally, the distance separating the coyotes was minimal and locations were separated by only a few minutes.

Coyotes were usually located weekly by ground or aerial radio-tracking. In addition, the mated pair was located twice a month at

1-hour intervals throughout a 24-hour period in April, May, and June 1976. Unmated coyotes were followed once a month. The mated pair was intensively monitored during evening hours from late June to mid-August 1976.

Four coyote vocal distances (Table 1) were determined in consultation with Dr. H. T. Gier to determine frequency of meaningful distances separating the mated pair during simultaneous locations.

The proximity of coyotes to den sites and the interactions of the mated pair were analyzed according to the biological seasons of coyotes (breeding, February; gestation, March and April; nursing, May and June; pup training, July and August through 15 September; adolescence, 16 September through 15 November; and pre-breeding, 16 November through January) described by Andelt and Gipson (in prep.).

The above calculations were made with an IBM 360 computer using programs developed at the University of Arkansas and the University of Nebraska. Home range ellipses and travel routes of coyotes were drawn with a Cal-Comp plotter.

RESULTS

Spatial and Temporal Interactions of a Mated Pair

Spatial and temporal relationships of a mated pair of coyotes (male 11 and female 14) were analyzed from 313 near simultaneous radio-locations of both coyotes from 7 April through 14 August 1976 (Table 2). Male 11 was captured on 3 December 1975. His trail, identified by a missing toe, was followed in snow for 12.6 kilometers (km) on 26, 28, and 31 January. The trail of another coyote was

within 100 meters (m) of his trail during the entire distance. Blood found in the trail of the second coyote indicated it was a female, probably female 14, in pro-estrous. Both coyotes were located together on 7 April, 3 days after a radio-transmitter was placed on female 14. They were often located together throughout the study and again in September and October (D. P. Althoff, pers. comm.).

The average and maximum distances the coyotes were located apart during each tracking shift decreased from gestation to nursing and pup training (Table 2). The coyotes traveled together on approximately 50 percent of the tracking shifts. Average distance traveled together was greater during nursing than pup training periods and ranged from 0 to 7.9 km per shift. The coyotes were not located "together" (less than 100 m apart) on either of two tracking shifts during gestation, but were together on 3 of 9 other days.

During gestation, nursing, and pup training periods combined the coyotes were located 16 percent of the time at the woof distance, 17 percent at the yip distance, 54 percent at the yip-howl distance, and 12 percent of the time they were out of contact. Little difference was evident in percent of time the coyotes were located at the four distance categories from daytime to night or from gestation to nursing and pup training (Table 3). Percent of locations at the woof distance during tracking shifts ranged from 0 to 50 during nursing and pup training (Table 2).

Proximity of Coyotes to Den Sites

Spatial and temporal relationships of coyotes 11, 13 and 14 to den sites were analyzed during 1976 and female 5 was monitored during

1975. Mates 11 and 14 utilized two different den sites. Site A was a complex of approximately eight dens located in a 400 m long, 3 m wide, and 2 m deep channelized dry creek bed surrounded by grain sorghum, wheat and a brome grass pasture. Site B included two dens located 1.7 km ESE of site A in a plum thicket surrounded by grain sorghum and wheat.

The mates utilized den site A until 10 June when we investigated the area. From 27 June to 10 July they utilized site B. From 30 June through 6 July the mates were also located near an old shed located approximately 230 m south of site B and surrounded by a wheat field. Coyote tracks and scats were found inside and evidence of digging was seen under the shed. Some pups may have been moved temporarily to this location. The mates centered most of their activity in grain sorghum fields less than 1 km north of site B from 15 July through the end of the study in mid-August. Grain sorghum fields were probably loafing areas for pups.

Data indicating the female whelped pups included locating two dead pups at site A on 27 June; the cause of their deaths was not determined. Coyote pup scats were located at den site B. A male pup was road-killed on 1 September within the home range of the mates, and a juvenile female outfitted with a radio-collar was often located near female 14 during autumn 1976 (D. P. Althoff, pers. comm.). Age of the dead pups indicated parturition occurred during the first week of May.

Female 13 was located near two den sites. Site C was in a 65 hectare native grass patch and site D, located 1.2 km west of site C,

was in a plum thicket surrounded by wheat and native grass. A juvenile male and female, radio-tagged during autumn 1976, often interacted with female 13 (D. P. Althoff, pers. comm.). She was shot on 6 November and her reproductive tract indicated she whelped 6 pups.

The average distance female 13 was from den site C was slightly less than the distance male 11 was from site A during tracking shifts of the breeding season (Table 2). During gestation and nursing, average distances females 13 and 14 were from their dens were approximately equal and less than the average distance of male 11. Male 11 and female 14 were approximately the same distance from dens during pup training.

The average distances male 11 was located from den sites during tracking shifts of pre-breeding, breeding, and gestation periods were approximately the same, decreased during nursing, and further decreased during pup training (Table 2). The average distance female 13 was located from her den sites decreased slightly from breeding to gestation and nursing. The average distances female 14 was located from her den sites were approximately equal during gestation, nursing, and pup training periods. The average of the maximum distances coyotes 11, 13 and 14 were found from dens during each biological season (Table 2) were approximately the same from one season to the next and from one coyote to the next with the exception that coyotes 11 and 14 did not appear to travel quite as far away from dens during the pup training period.

Frequency of locations at den sites during daytime and nights is presented in Table 4. Few locations of coyote 13 were "near" (within 200 m) her den during pre-breeding and breeding. Male 11 was seldom

located near his den at night during these two periods, but was frequently located near the den site during daytime.

Male 11 and female 13 were seldom located near dens during the night, but were located near dens approximately 20 percent of the time during daytime of the gestation period. Female 14 was located approximately 20 percent of the time near den sites during the night and approximately 62 percent of the time during daytime of gestation.

Females 13 and 14 were located near den sites approximately 60 and 50 percent of the time, respectively, during daytime and 30 percent of the time during the night of the nursing period. Male 11 was located near dens approximately 13 percent of the time during the day and also at night.

Male 11 and female 14 were located 25 and 44 percent of the time, respectively, near dens during daytime of pup training. During the evening, both coyotes were located near dens approximately 36 percent of the time.

All three coyotes usually made one or two trips to the den sites (Table 2) during each tracking shift during the nursing period (Fig. 1). Male 11 and female 14 usually made one or two trips to their den sites during the early pup training period (Fig. 2).

Male 11 and female 14 were apparently responsible for numerous turkey losses from 4 June through 14 August (Andelt and Gipson, in prep.). During 15 tracking shifts of this period, male 11 made 24 trips to the pups; he was in the turkey pen on 14 occasions and returned to his pups within 2 hours on 11 of these. During these shifts female 14 made 33 trips to her pups, she was in the turkey pen on 11 occasions

and returned to the pups each time.

Female 5 was approximately 13.5 months old when captured on 12 June. She did not have pups, but centered her activity around two areas on three tracking shifts during pup training (Fig. 2). Dens and pup tracks were located on 19 July at one of the areas. She was probably serving as a nurse maid for another female's pups.

DISCUSSION

Spatial and Temporal Interactions of a Mated Pair

Snow and radio-tracking information indicated a mated pair of coyotes interacted often during spring and summer 1976 and were possibly closely associated as early as late January and were still together in late October. Seton (1929) indicated coyote pairs run, hunt, and live together in winter or summer. Ryden (1975) observed the same pair of coyotes raised pups during two consecutive seasons. Radio-tracking our mated pair indicated they were usually within 100 m of each other at least once during each tracking shift. They were seldom out of vocal contact and usually appeared to be aware of the other's location. During approximately 50 percent of our tracking shifts the mates traveled together. Ryden (1975) observed a mated pair of coyotes in a protected area and noted the male and female left the den to hunt together nearly every evening. When our mated pair traveled together, they were probably involved in coordinated hunting activities.

Proximity of Coyotes to Den Sites

Radio-tracking indicated male 11 was often located near future

den sites as early as the pre-breeding and breeding seasons, but female 13 was seldom near her future den during the same periods. During gestation and nursing periods females were more often located near den sites than a male, possibly due to den preparation and nursing pups. A male was located near dens almost as often as his mate during pup training. The male of a mated pair appeared as important as the female in carrying food to their pups as evidenced by the large number of return trips to their pups from a turkey pen during late June, July and the first half of August.

One of our females did not have pups, but was probably serving as a nursemaid. Ryden (1975) observed a mated pair of coyotes raising pups and noted the pair had male and female nursemaids. She also noted one adult would usually stay near the den while the others were away. Our mated pair did not show any synchrony in departure or arrival at den sites.

This was the first study which intensively documented the relationship of coyotes to den sites and to each other. A pair of coyotes was closely associated during most of the year and both appeared important in pup raising.

ACKNOWLEDGMENTS

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University of Nebraska Research Council; Nebraska Agricultural Experiment Station; Nebraska Wool Growers; Bevans Turkey Farm; Nebraska Registered Sheep Breeders; and the Eagle Nebraska Coyote Hunting Club.

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National Oceanic and Atmospheric Administration. 1975. Local climatological data: Annual summary with comparative data, 1975, Lincoln, Nebraska. National Climatic Center, Federal Building, Asheville, North Carolina, 4pp.

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Department of Poultry and Wildlife Sciences, University of Nebraska, Lincoln, Nebraska 68583.

Fig. 1.—Home range ellipses (Gipson and Sealander; 1972) and travel routes of mated coyotes 11 and 14, during the nursing period showing concentrated activity around den sites and movements between the dens and a turkey pen; and movements around dens by female 13.

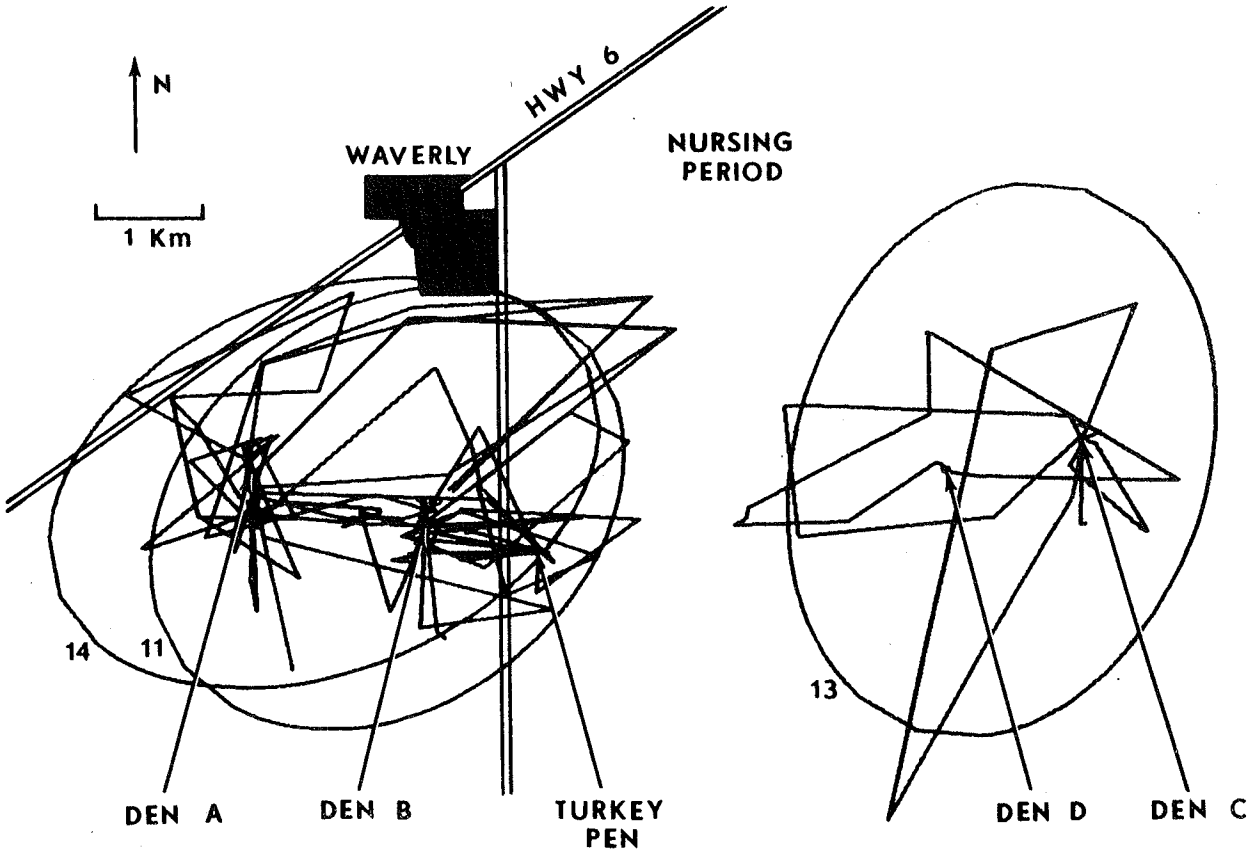
N
1 Km
HWY 6
WAVERLY
NURSING
PERIOD
14
11
13
DEN A
DEN B
TURKEY
PEN
DEN D
DEN C

Fig. 2.—Home range ellipses and travel routes of mates 11 and 14 during the early pup training period showing movements between den site B and a turkey pen, and the movements of female 5 around two areas where she was probably helping raise another female's pups.

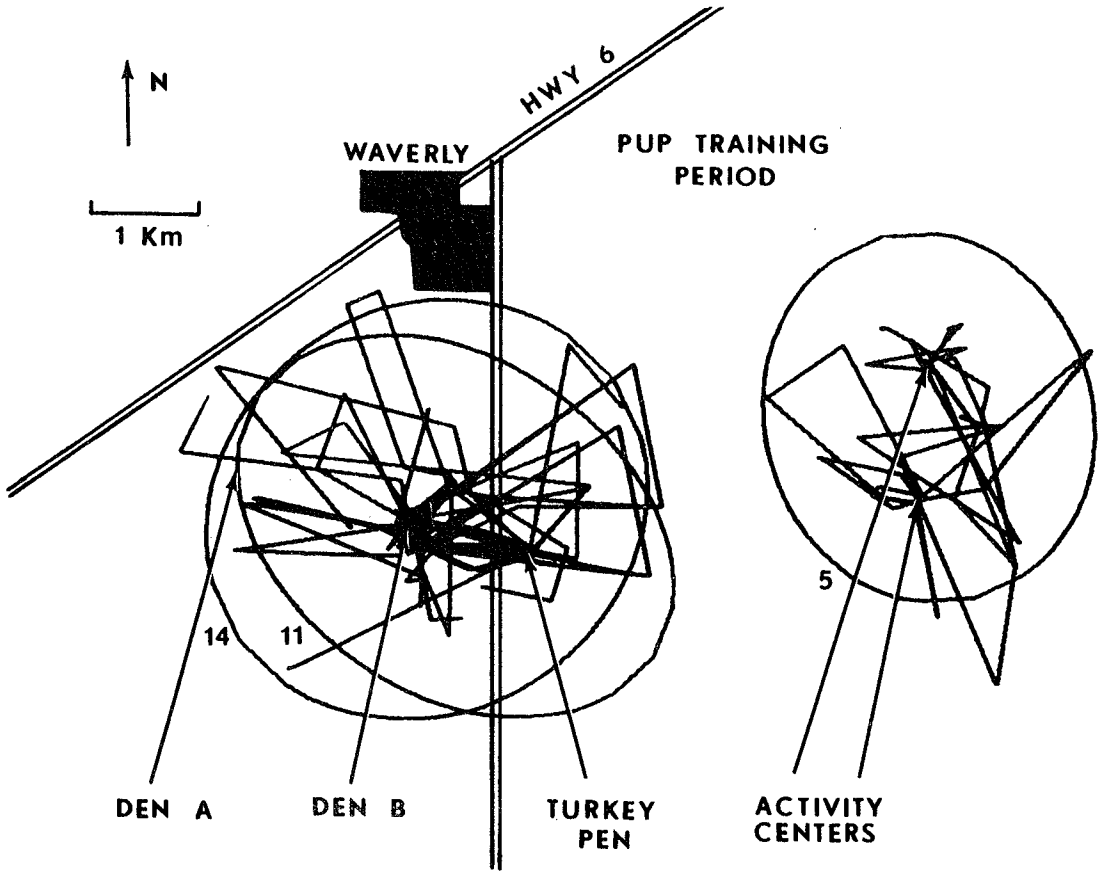
N
1 Km
HWY 6
WAVERLY
PUP TRAINING
PERIOD
14
11
5
DEN A
DEN B
TURKEY
PEN
ACTIVITY
CENTERS

Table 1. Coyote vocal distances.

Distance	Interval	Characterization
Woof	<100 m	Low amplitude woof; visual contact; traveling, resting, or rendezvousing together
Yip	100-400 m	High pitched yip, some visual contact, aware of other's presence
Yip-Howl	400-2000 m	Long distance vocalization, little visual contact, independent activities, may be aware of other's location
Out of Contact	>2000 m	Out of vocal and visual contact

Table 2.—Proximity of male 11 and females 14 and 13 to den sites and spatial relationships of a mated pair, male 11 and female 14, during radio-tracking shifts.

Date[a]	Distance Apart (km) Ave.	Distance Apart (km) Max.	% Fixes <100 m Apart	Distance Traveled Together	Proximity to Dens: Distance from Den (km) Mean 11	Mean 14	Mean 13	Maximum 11	Maximum 14	Maximum 13	Trips to Den 11	Trips to Den 14	Trips to Den 13
Pre-breeding													
14-15 Dec					2.4			3.6			0		
11-12 Jan					1.6			3.7			0		
MEAN					2.0			3.7			0		
Breeding													
12-13 Feb					1.5		1.1	3.9		3.0	1		0
Gestation													
9-10 Mar					1.8		0.9	4.4		2.8	0		0
8- 9 Apr	2.4	4.3	0	0	2.1	0.3	0.6	3.9	0.8	2.1	0	0	1
25-26 Apr	1.6	2.0	0	0	1.8	0.6	___	2.2	1.9	___	0	2	_
MEAN	2.0	3.2	0	0	1.9	0.5	0.8	3.5	1.4	2.5	0	1	0.5
Nursing													
9-10 May	1.1	1.9	23	7.9	1.8	0.9	0.7	4.1	4.0	4.0	0	0	1
10-11 May	1.0	2.1	33	1.1	0.9	0.4	0.6	1.9	1.9	2.7	1	2	3
25-26 May	1.3	3.9	24	0.9	1.5	0.4		3.3	1.3		0	1	
8- 9 Jun	1.1	3.0	17	7.1	1.2	1.0	0.6	4.2	4.2	2.1	2	2	1

27-28 Jun	0.5	1.7	0	0	0.5	0.3		2.0	1.5		1	6	
28-29 Jun	1.1	2.0	0	0	0.5	0.7		1.1	2.1		1	2	
29-30 Jun	1.6	3.5	11	0	0.7	1.0		2.5	2.2		1	1	
MEAN	1.1	2.6	15.4	2.4	1.0	0.7	0.6	2.7	2.5	2.9	0.9	2.0	1.7
Pup training													
30- 1 Jul	1.0	3.3	0	0	0.7	0.6		2.3	1.7		1	3	
1- 2 Jul	0.2	0.4	33	5.3	0.7	0.7		2.5	2.5		1	1	
4- 5 Jul	0.5	1.8	36	1.3	0.8	0.5		1.7	1.6		2	2	
5- 6 Jul	0.6	1.6	33	3.7	0.7	0.7		2.2	2.2		2	3	
6- 7 Jul	0.4	1.1	22	0	0.4	0.3		0.9	1.2		2	2	
9-10 Jul	0.5	2.0	50	1.0	0.6	0.7		1.7	1.7		2	1	
15-16 Jul	0.9	2.4	11	0	0.7	1.2		1.4	2.2		1	1	
19-20 Jul	0.8	1.9	11	0.3	MEAN 0.7	0.7		1.8	1.9		1.6	1.9	
28-29 Jul	0.8	2.4	27	7.3									
11-12 Aug	1.3	2.2	0	0									
13-14 Aug	1.1	2.2	13	0									
MEAN	0.7	1.9	21	1.7									

[a]Calculations were based upon 24 or 25 consecutive hour locations from 14-15 Dec through 27-28 Jun except 13 locations were made on 9-10 May. On all subsequent dates, calculations were based upon 8 to 12 hourly locations from 2000 to 0800.

Table 3. Distance associations of mates 11 and 14 during the gestaion, nursing, and pup training periods.

	Radio-locations							
	Gestation		Nursing		Pup Training		Total	
Distance	Day	Night	Day	Night	Day	Night	Day	Night
Woof (< 100 m)	3	0	14	11	2	21	19	32
Yip (100-400 m)	5	0	12	7	10	20	27	27
Yip-Howl (400-2000 m)	23	12	43	35	9	47	75	94
Out of Contact (> 2000 m)	4	12	3	14	0	6	7	32

Table 4. Proximity of male 11 and females 14 and 13 to den sites.

	Radio-Locations																							
	Pre-Breeding				Breeding				Gestation						Nursing						Pup Training			
	Day		Night		Day		Night		Day			Night			Day			Night			Day		Night	
Distance	11	13	11	13	11	13	11	13	11	14	13	11	14	13	11	14	13	11	14	13	11	14	11	14
< 200 m	18	0	2	0	9	1	1	0	13	25	10	1	4	0	11	40	28	8	20	6	2	4	18	16
> 200 m	25	5	28	0	8	17	12	13	44	15	41	35	20	25	71	39	17	54	42	15	6	5	30	30